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Full Length Research Paper

Effect of salinity on growth and leaf area of sunflower (*Helianthus annuus* L.) cv. suntech - 85

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A pot experiment was conducted during 2009 to 2010 to access adverse effect of salinity on growth of sunflower (*Helianthus annuus* L.) cv. Suntech - 85. The result revealed that with increasing salinity concentration, the growth parameters declined except at lower salinity level 5 E.C. which does not show any adverse effect rather, there was slight increase in all growth parameters as compared to control. Whereas, higher salinity level with 25 E.C. was deleterious and showed a decrease of 20.96, 39.92 and 22.44% in shoot length, 35.93, 33.33 and 31.50% in root length, 56.46, 29.95 and 28.81% in shoot fresh weight, 42.42, 51.28 and 34.73% in root fresh weight, 30.26, 45.54 and 27.08% in shoot dry weight, 63.41, 55.00 and 57.29% in root dry weight and 44.82, 42.30 and 38.14% in leaf number and 41.56, 33.04 and 40.00% in leaf area as compared to control at 30, 60 and 90 DAS respectively. This decrease in growth at higher salinity levels might be due to the toxic effects of salinity, which badly affected plant physiological aspects such as osmotic adjustment and ion accumulation creating drought-like conditions for the plant.

Key words: Growth, salinity, leaf area, sunflower (*Helianthus annuus* L.).

INTRODUCTION

Saline and sodic soils occur naturally in arid and semi-arid climate conditions and is a major problem in crop production (Szaboles, 1994). It is estimated that one third of the irrigated land in the world is affected by high salinity (Mass and Hoffmann, 1976). About ten million-hectare lands are affected by high salinity and sodicity in India alone. Moreover, Uttar Pradesh had about 1.28 million hectare area under saline-alkali soils of which 4,000 to 20,000 ha land occurs in Shahjahanpur district of Uttar Pradesh (Srivastava et al., 2002).

Salinity limits the crop production and yield. Plants growing in saline atmosphere suffer some degree of water and salt stress, which affects every aspect of plant growth and development, as all the phases of plant growth from germination to maturity are affected by the environment in which the plant grows (Boyer 1982; Kumar et al., 2007).

When it comes to the production of oil seed crops, salinity plays a limiting factor in their production; oil crops occupy a prime importance in Indian economy (Sharma, 2003). The maximum oil production in India during 2003 to 2004 was 25.1 million tons, which was 14 million ton less than self dependency in oil production. In India per day availability of vegetable oil per person is 12 g which should be 18 g per person according to F. A. O report (Hedge, 2004).

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Table 1. Effect of salinity on shoots and roots length in *Helianthus annuus* L. cv. *Suntech-85* at 30, 60 and 90 days after sowing (DAS) stages.

Salinity concentrations (E.C.)	Length (cms)					
	30 DAS		60 DAS		90 DAS	
	Shoot	Root	Shoot	Root	Shoot	Root
0	20.66	10.66	79.33	15.00	104.00	18.00
5	21.00	11.00	81.00	15.33	104.33	18.33
10	19.33	10.33	70.66	14.00	99.33	17.33
15	18.00	9.66	67.66	13.00	95.33	16.33
20	16.66	7.66	60.00	12.00	91.00	14.33
25	16.33	6.83	47.66	10.00	80.66	12.33
C.D at 5% =	1.50	1.51	5.37	1.22	5.72	1.47

N. B. = Each value is a mean of three replicates, E. C. = Electric conductivity, D. A. S. = Days After Sowing.

Table 2. Effect of salinity on fresh weights of shoots and roots in *Helianthus annuus* **L.** cv. *Suntech*-85 at 30, 60 and 90 days after sowing (DAS) stages.

Salinity concentrations (E.C.)	Fresh weight (g)					
	30 DAS		60 DAS		90 DAS	
	Shoot	Root	Shoot	Root	Shoot	Root
0	6.50	0.66	17.13	1.56	98.33	7.66
5	7.16	0.70	18.13	1.66	110.00	8.16
10	5.86	0.56	15.50	1.43	94.00	7.50
15	4.23	0.52	14.83	1.33	86.66	6.50
20	3.43	0.46	13.33	0.93	78.33	5.43
25	2.83	0.38	12.00	0.76	70.00	5.00
C.D at 5% =	1.18	0.10	2.02	0.27	8.60	0.86

N. B. = Each value is a mean of three replicates, E. C. = Electric conductivity, D. A. S. = Days After Sowing.

In the present study an attempt has been made to observe the effect of different salinity concentrations on growth parameters of sunflower (*Helianthus annuus* L.) cv *Suntech - 85*.

MATERIALS AND METHODS

The experiment was conducted at Department of Botany, G. F. (P. G.) College Shahjahanpur, Uttar Pradesh, India, on sunflower (*H. annuus* L.) cv. *Suntech - 85*. The experiment was set in 9 inches earthen pots in factorial randomized manner containing a mixture of garden soil, humus and sand in a ratio of 2:1:1 in a net house. Artificially prepared different grades of salinity concentrations *viz*, 0, 5, 10, 15, 20 and 25 electrical conductivity (E. C.) were prepared by mixing salts of sodium chloride, calcium chloride and sodium sulphate in a ratio of 7:2:1 and were applied to pots periodically. Analysis was done by uprooting the plants carefully and washed thoroughly under running tap water, the shoot and root lengths were taken with the help of meter scale. The fresh weight of shoot and root was taken on single pan balance, and for the dry weight of shoot and root the plants were kept in an hot air oven at 60°C and after seven days the dry weight was taken on single pan balance. The leaf number was calculated by counting number of leaves per plant and the total leaf area of plant was determined with the help of Kemp's constant method.

RESULTS

The results presented in Tables 1 and 2 showed that with the increasing concentrations of salinity there was gradual decline in shoot and root length but there was slight increase of 1.65, 2.11 and 0.32% in shoot length, 3.19, 2.20 and 1.83% in root length as compared to control at 30, 60 and 90 DAS, respectively. Whereas, at maximum concentration of 25 E.C., there was 20.96, 39.92 and 22.44% decrease in shoot length and 35.93, 33.33 and 31.50% decrease in root length (Graphs I and II). In fresh weight of shoot and root at 5 E.C., there was 10.15, 5.84 and 11.87% increase in shoot fresh weight and 6.06, 6.41 and 6.53% increase in root fresh weight. At 25 E. C. concentration, the decrease was 56.46, 29.95 and 28.81% in shoot fresh weight and 42.42, 51.28 and 34.73% in root fresh weight (Graphs III and IV). Similarly, in shoot and root dry weight at 5 E. C. there was 6.58, 1.41 and 6.94% increase in shoot dry weight and 4.88, 3.75 and 10.42% increase in root dry weight but at 25 E. C. there was 30.26, 45.54 and 27.08% decrease in shoot dry weight and 63.41, 55.00 and 57.29% decrease in root dry weight (Graphs V and VI). Whereas, similar trends

Table 3. Effect of salinity on dry weights of shoots and roots in ***Helianthus annuus* L.** cv. *Suntech-85* at 30, 60 and 90 days after sowing (DAS) stages.

Salinity concentrations (E.C.)	Dry weight (g)					
	30 DAS		60 DAS		90 DAS	
	Shoot	Root	Shoot	Root	Shoot	Root
0	0.76	0.41	2.13	0.80	5.76	0.96
5	0.81	0.43	2.16	0.83	6.16	1.06
10	0.73	0.35	1.86	0.68	5.68	0.73
15	0.68	0.28	1.66	0.55	4.96	0.63
20	0.57	0.18	1.43	0.40	4.70	0.48
25	0.53	0.15	1.16	0.36	4.20	0.41
C.D at 5% =	0.21	0.05	0.31	0.06	0.38	0.14

N. B. = Each value is a mean of three replicates, E. C. = Electric conductivity, D. A. S. = Days After Sowing.

Table 4. Effect of salinity on leaf number in *Helianthus annuus* L. cv. *Suntech-85* at 30, 60 and 90 days after sowing (DAS) stages.

Salinity concentrations (E.C.)	Leaf number		
	30 DAS	60 DAS	90 DAS
0	9.66	17.33	14.00
5	10.33	19.33	15.33
10	9.33	15.33	12.66
15	8.33	14.33	11.33
20	7.00	12.33	10.66
25	5.33	10.00	8.66
C.D at 5% =	1.19	2.69	1.83

N. B. = Each value is a mean of three replicates, E. C. = Electric conductivity, D. A. S. = Days After Sowing.

Table 5. Effect of salinity on leaf area in *Helianthus annuus* L. cv. *Suntech-85* at 30, 60 and 90 days after sowing (DAS) stages.

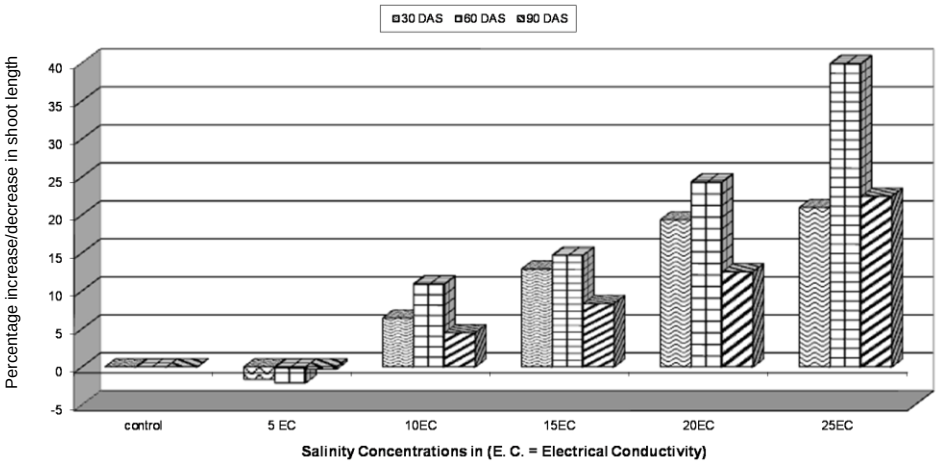
Salinity concentrations (E.C.)	Leaf area		
	30 DAS	60 DAS	90 DAS
0	205.33	373.33	250.00
5	245.33	403.33	303.33
10	176.66	343.33	226.66
15	160.00	310.00	196.66
20	140.00	280.00	176.66
25	120.00	250.00	150.00
C.D at 5% =	29.14	49.37	43.00

N. B. = Each value is a mean of three replicates, E. C. = Electric conductivity, D. A. S. = Days After Sowing.

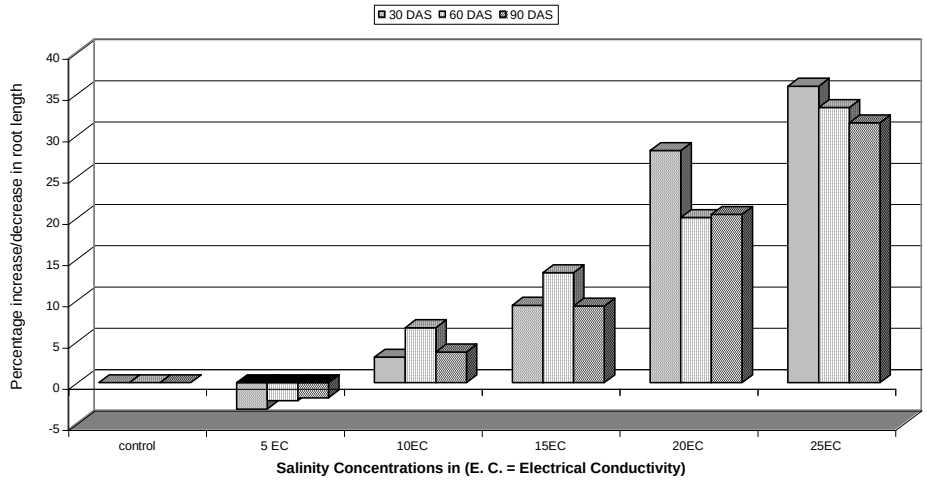
were also revealed in leaf number and leaf area at concentration of 5 E. C. there was 6.94, 11.54 and 9.50% increase in leaf number and 19.48, 8.04 and 21.33% increase in leaf area as compared to control at 30, 60 and 90 DAS, respectively. But at 25 E. C. concentration, it showed 44.82, 42.30 and 38.14% decrease in leaf number and 41.56, 33.04 and 40.00% decrease in leaf area as compared to control at 30, 60 and 90 DAS, respectively (Graphs VII and VIII).

DISCUSSION

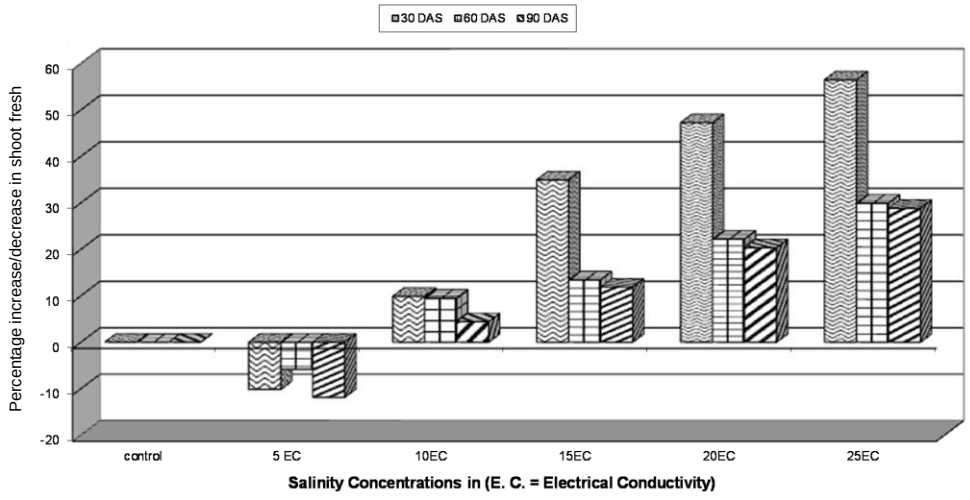
It is an established fact that salinity inhibits plant growth. Generally plants growing in saline atmosphere face water deficit as similar to the drought stress. The water



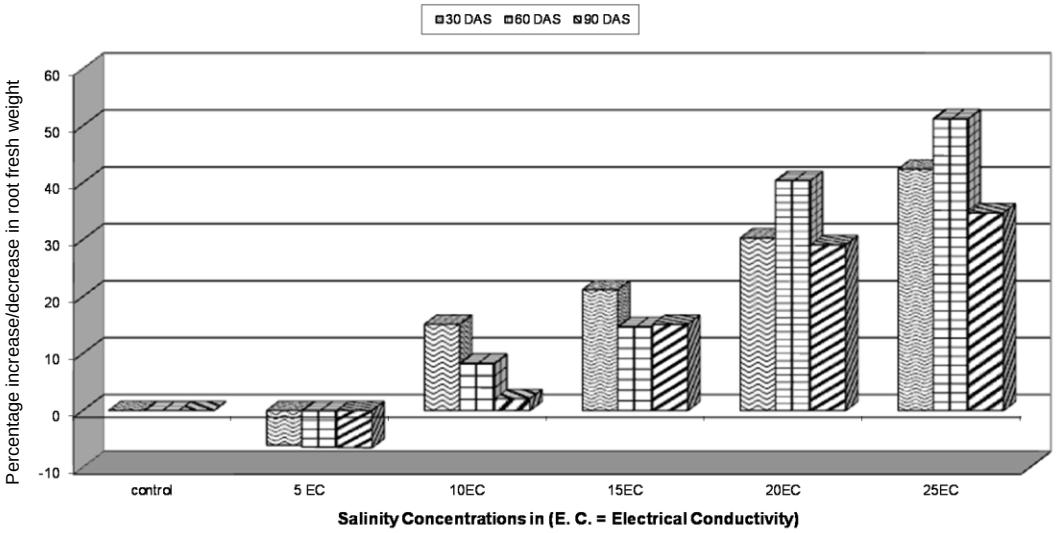
Graph I. Effect of salinity on Shoot length of Sunflower cv Suntech -85 after 30, 60 and 90 DAS.



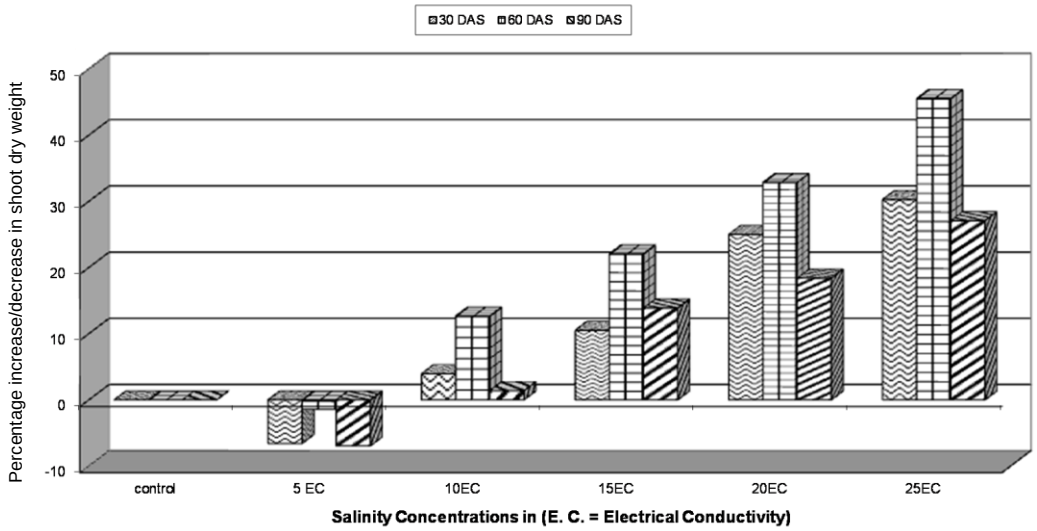
Graph II. Effect of salinity on Root length of Sunflower cv Suntech -85 after 30, 60 and 90 DAS.



Graph III. Effect of salinity on shoot fresh weight of Sunflower cv Suntech –85 after 30, 60 and 90 DAS.



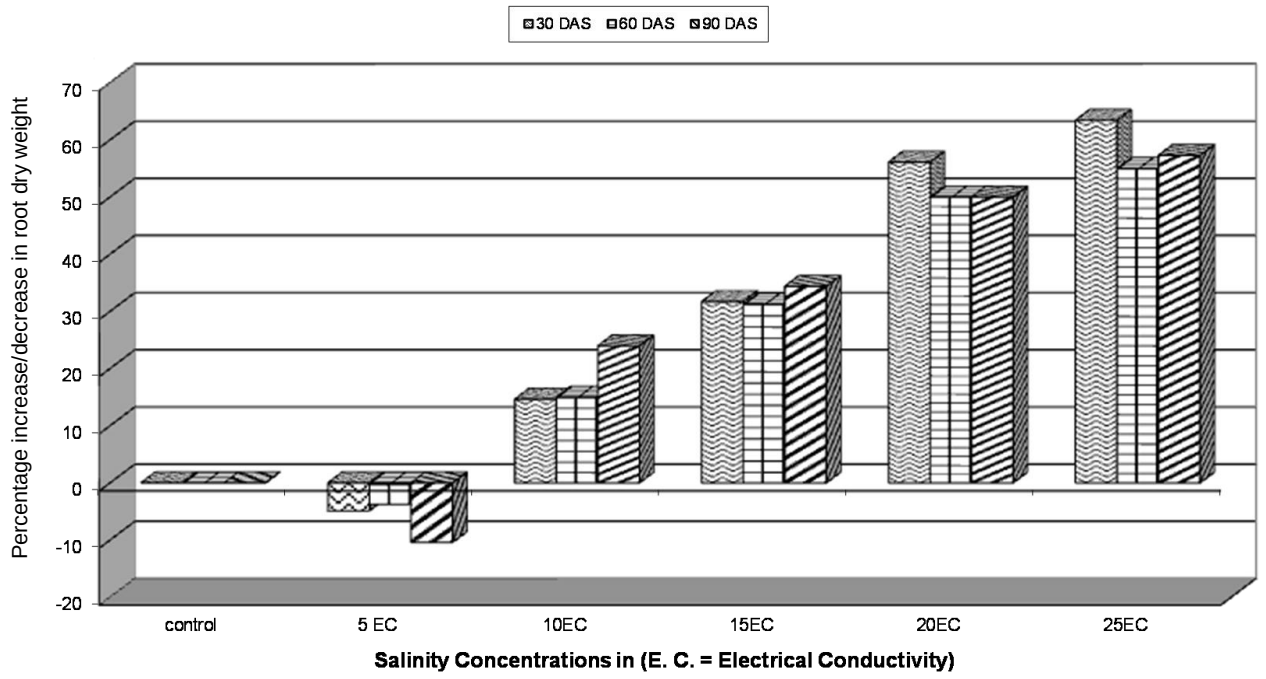
Graph IV. Effect of salinity on root fresh weight of Sunflower cv Suntech -85 after 30, 60 and 90 DAS.



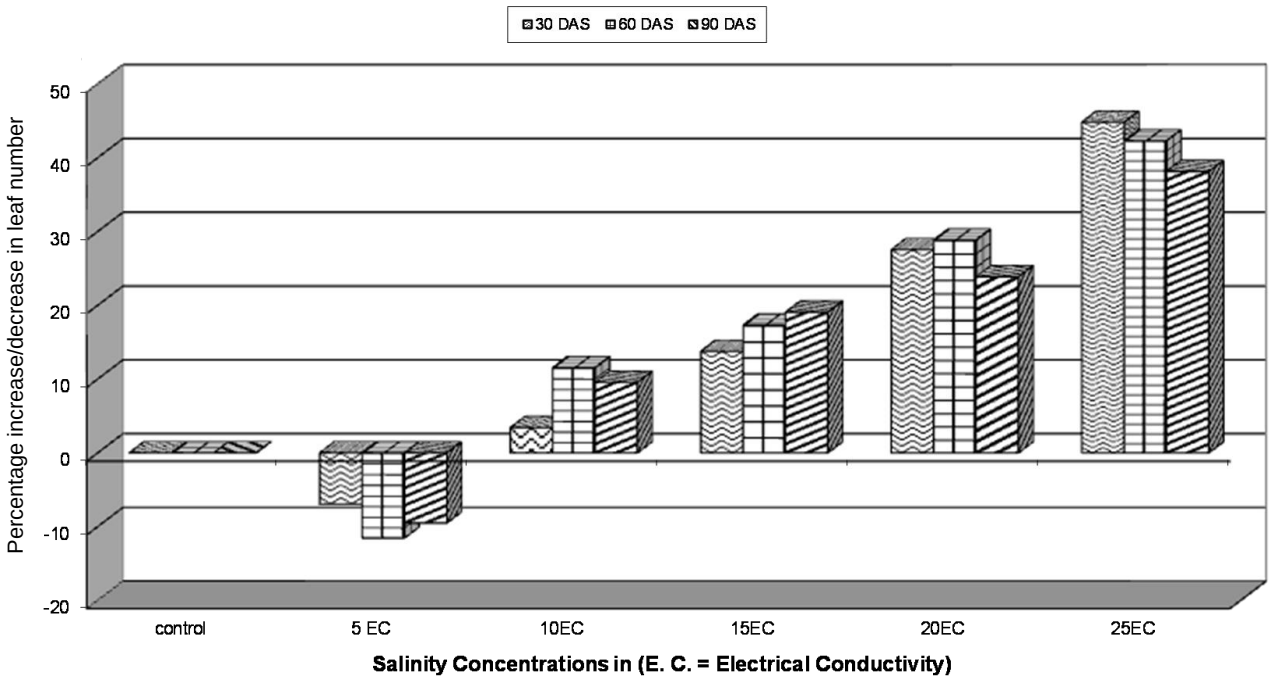
Graph V. Effect of salinity on Shoot dry weight of Sunflower cv Suntech -85 after 30, 60 and 90 DAS.

potential of plants growing in saline soil became low due to increasing concentration of salts in root zone (Munns and Termaat, 1986). Excessive amount of salt in root zone affects growth of root, photosynthesis, enzyme activation and nutrient uptake and ultimately decreasing plant growth (Delane et al., 1982).

Results from the above study indicate that *H. annuus* cv. *Suntech-85* is a moderate salt tolerant species during growth and can withstand the salinity level upto 5 E. C. conentration. Infact all the growth parameters show a little enhancement (Tables 1 to 5 and Graphs I to VIII) over the control in 5 E. C. treatment. Generally, the halophytes show a stimulation of growth at this concentration which is otherwise inhibitory to the growth of glycophytes. However, Salinity level higher than 5 E. C. level decreased all the growth parameters in this study as reported by several workers in other oil crops e.g. groundnut (Mensah et al., 2006), cotton (Maiti et al., 2006), mustard (Sadiq et al., 2002; Kumar et al., 2005, 2007), soybean (Shereen et al., 2001) and safflower (Kaya and Ipex, 2003). Similar results have also been reported in Leaf area which is a good indicator of water and salinity stress, since leaf expansion generally requires a high turgor pressure for cell enlargement directly affecting photosynthetic rate and growth (Huang and Redmann, 1995).



Graph VI. Effect of salinity on Root dry weight. of Sunflower cv Suntech -85 after 30, 60 and 90 DAS.



Graph VII. Effect of salinity on leaf number of Sunflower cv Suntech -85 after 30, 60 and 90 DAS.

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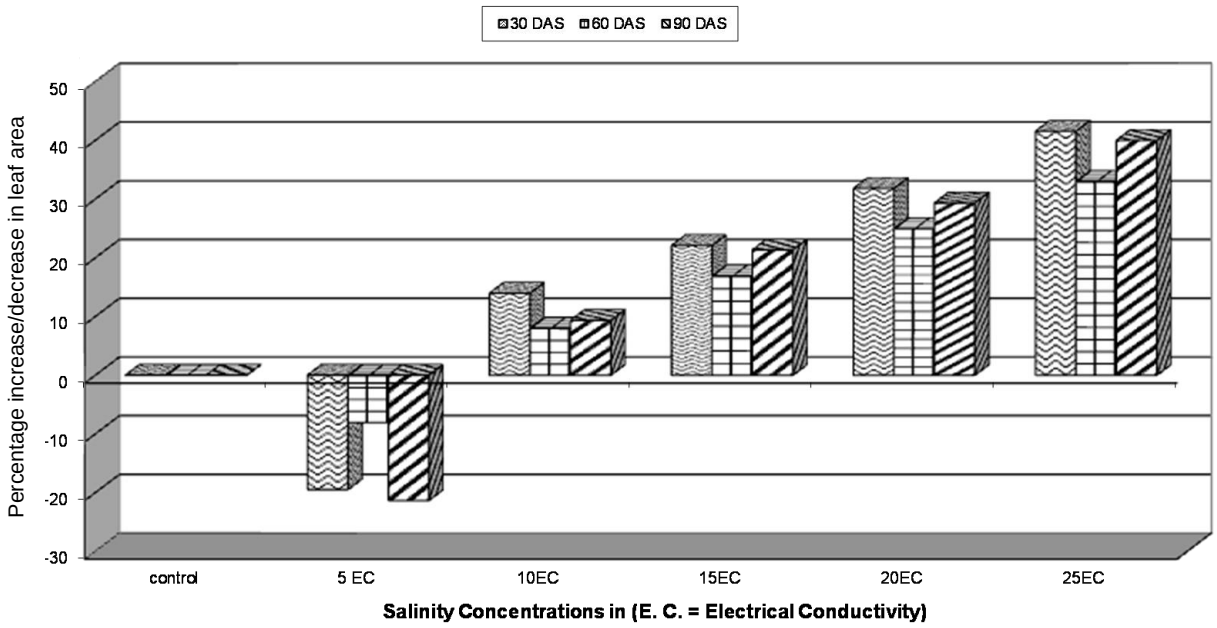

Graph VIII. Effect of salinity on leaf area of Sunflower cv Suntech –85 after 30, 60 and 90 DAS.

out research work.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Biochemical responses of Sankankuppi (*Clerodendron inerme* L.) to salinity stress

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The present investigation was made to study the effect of different concentrations of sodium chloride on biochemical activity in different parts of *Clerodendron inerme.* The plant could survive a wide range of 100 to 500 mM of NaCl concentrations. The upper limit for the survival of this species was 500 mM NaCl. However, favorable growth response by seedling was confined to 200 mM NaCl. Biochemical compounds such as amino acid, sugar, protein, proline, glycinebetaine, and pigment chlorophyll content was increased up to 200 mM NaCl.

Key words: Halophyte, biochemical, salinity.

INTRODUCTION

Worldwide, more than 800 million hectares of land are salt affected, and tolerance to this salinity differs greatly among plant species (Munns and Tester, 2008). In India alone, about 30 million hectares of coastal land is lying barren and uncultivable because of soil affected by salinity.

Stresses associated with temperature, salinity and drought single or in combination are likely to enhance the severity of problems in the coming decades (Claussen et al., 1985). Salt stress in soil or water is one of the major stresses especially in arid and semi-arid regions and can severely limit plant growth and productivity (Allakhaverdiev et al., 2000; Koca et al., 2007).

Plant water stress is often the most prominent physiological response associated with increase in soil and / or water salinity (Munns, 2002). Salt tolerance has been attributed as the primary factor in shaping vegetative structures, including biomass and species composition of coastal and estuarine wetlands (Bertness, 1991; Pennings et al., 2001).

The ability to undergo rapid osmotic adjustments is important for plants residing in brackish marshes where both water availability and salinity may fluctuate considerably over a single tidal period (Woernor and Hackney, 1997). Controversial data exist regarding the question of whether halophytes require saline conditions for their existence and vigorous growth or merely tolerate them. Halophytes vary in their requirement of NaCl for optimum growth and photosynthesis. Adaptation of halophytes to salty conditions includes high tolerance for the negative effects of salinity as well as positive reaction towards it. One of the major factors in the salt tolerance is believed to be the existence of succulence.

Halophytes survive salt concentration equal to or

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greater than that of seawater and possess physiological mechanisms that maintain lower water potential inside the cell than that in the soil (Ungar, 1991). Salt tolerance in halophytes is brought about by a variety of physiological mechanisms and morphological adaptations. Adaptations of halophytes to the saline environment include high tolerance for the negative effect of salinity as well as positive reaction towards it. The compartmentation of ions in the vacuoles and accumulation of compatible solutes in the cytoplasm and presence of genes for salt tolerance confer salt resistance to halophytes (Gorham, 1995).

Clerodendron inerme is a straggling shrub, native to India. The branches are slender, glabrous and green throughout the year. It was naturally growing in abundance on both sides of sea-coasts in tidal forest. This species are used for Guam, the bitter root, leaves and wood are used by natives as a remedy for intermittent fevers. Leaves and roots, in tincture and decoction, used as substitutes for quinine. Elsewhere the root, boiled in oil, is applied like a liniment for rheumatism.

The present study was made to investigate the salt tolerance of *C. inerme*.

MATERIALS AND METHODS

Plant material

The mature stem cuttings were collected from salt marshes in the mangrove area of Pichavaram, on the east coast of Tamilnadu, India about 10 km east of Annamalai University Campus.

Growth conditions

The stem cutting of *C. inerme* (3 cm long with one node and 2 opposite leaves) was propagated and planted individually in polythene bags (7"× 5") filled with homogenous mixture of garden soil containing red earth, sand and farm yard manure (1:2:1). The cuttings were irrigated with tap water and maintained in the Botanical Garden, Annamalai University.

Salt treatment and experimental design

One month old well established cuttings were selected and treated with varying concentrations of NaCl (100 to 1000 mM). The experimental yard was roofed with transparent polythene sheet at a height of 3 m from the ground in order to protect the plants from rain.

Sampling for various studies was taken on the 60th day after NaCl treatment. The free amino acid, total sugar, starch, protein, proline, glycinebetaine and pigment content were estimated.

Determination of biochemical parameters

Leaf, stem and root tissues were treated with 80 % boiling ethanol for taking extractions (5 ml extract representing 1 g tissue). One ml of ethanol extract was taken and neutralized with 0.1 N NaOH using methyl red indicator. One ml of Ninhydrin reagent was added. The content was boiled in a water bath for 20 min. To the test tube, 5 ml of diluting solution (Equal volume of distilled water and n-propanol) was added, cooled and diluted to 25 ml with distilled water. The absorbance was measured at 570 nm in a Spectrophotometer (U-2001, HITACHI). The free amino acids were determined using the method of Moore and Stein (1948).

The total sugar content was determined according to Nelson (1944). 1 ml of ethanol extract taken in the test tubes was evaporated in a water bath. To the residue, 1 ml each of distilled water and 1N H_2SO_4 were added and incubated at 49°C for 30 min. The solution was neutralized with 1 N NaOH using methyl red indicator. 1 ml of Nelson reagent was added to each test tube. The test tubes were heated for 20 min in a boiling water bath, cooled and 1 ml of arsenomolybdate reagent was added. The solution was thoroughly mixed and diluted to 25 ml and read at 495 nm in a Spectrophotometer (U-2001, HITACHI).

The total protein content in the plant sample was determined using a Spectrophotometer procedure as per Lowry et al. (1951). 500 mg of plant tissues was well grained with pestle and mortar using 10 ml of 20% TCA. The homogenate was centrifuged for 15 min at 6000 rpm; thereafter the supernatant was discarded. To the pellet, 5 ml of 0.1 N NaOH was added and centrifuged. The supernatant was saved and made to 5 ml with 0.1 N NaOH. From the extract, 0.5 ml of the sample was taken in a 10-ml test tube and 5 ml of reagent 'C' was added. The solution was mixed well and made to stand for 10 min in darkness. Later, 0.5 ml of Folin-Phenol was added with vigorous mixing. The mixture was kept in dark for 30 min. The sample was read at 660 nm in a Spectrophotometer (U-2001, HITACHI). Blank was prepared without protein sample. Standard graph of protein was prepared by using 5th fraction of Bovin's Serum Albumin.

The proline activity was assayed according to Bates et al. (1973). Five hundred mg of plant tissue was homogenized in 10 ml of 3% aqueous sulphosalicylic acid. The homogenate was filtered through Whatmann No.42 filter paper. Two ml of acid ninhydrin (1.25 g ninhydrin in 30 ml of glacial acetic acid and 20 ml of 6 M phosphoric acid) and 2 ml of glacial acetic acid in a test tube was heated for an hour at 100°C. The reaction mixture was extracted with 4 ml of toluene and mixed vigorously by using a Vortex mixture for 15 to 20 s. The chromophore containing toluene was aspirated from the aqueous phase. The absorbance of the toluene layer was measured in a Spectrophotometer at 520 nm using toluene as blank.

The glycinebetaine content in the plant sample was determined using a Spectrophotometer procedure of Grieve and Grattan (1983). Five hundred mg of finely ground dried plant samples was mechanically shaken with 20 ml of de-ionized water for 24 h at 25°C. Time required for this step was determined by extracting the plant samples for 1, 4, 16, 24 and 48 h. The samples were then filtered and filtrates were stored in the freezer for analysis. Thawed extracts were diluted with 2 N H_2SO_4 (1:1). The acid potassium tri-iodide solution for total QACs was prepared by dissolving 7.5 g resublimed iodine and 10 g potassium iodide in 1 M HCl and filtered (Speed and Richardson, 1968). Precisely, 0.2 ml of acid potassium tri-iodide reagent was added to an aliquot of sample containing between 10 to 15 µg of QACs in water. The mixture was shaken and left for at least 90 min in an ice bath with intermittent shaking. Two ml of ice-cold water was added rapidly to the mixture to reduce the absorbance of blank and to improve replication. This was quickly followed by 10 ml of 1, 2-dichloroethene in ice, and the 2 layers mixed well and kept at 4°C (Storey and Wyn Jones, 1977). The absorbance of the lower organic layer was measured at 365 nm in a Spectrophotometer. The results are expressed as glycinebetaine equivalent by using glycinebetaine for standard value.

500 mg pigments assays of fresh leaf tissue of each treatment was extracted in 10 ml 80% acetone and absorbance of extracts was recorded at 645 and 663 nm as per Arnon (1949).

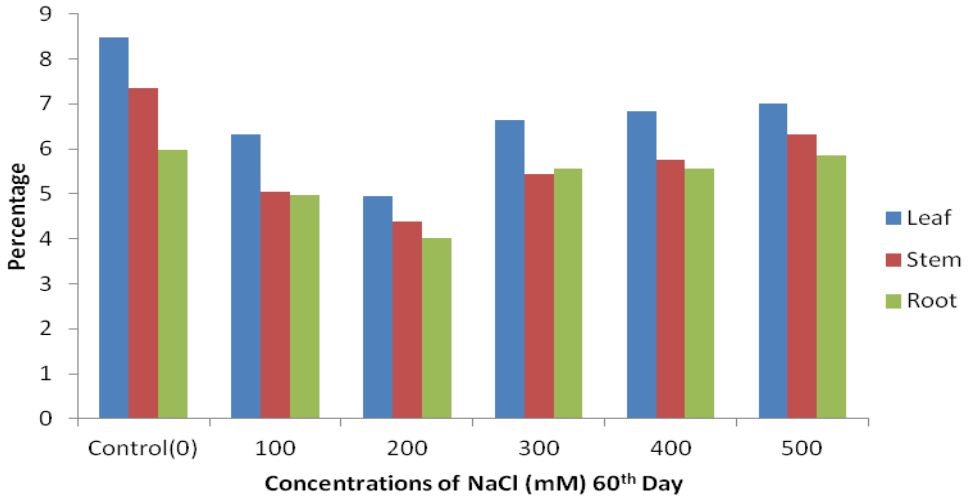

Figure 1. Effect of NaCl on amino acid content (mg/g fr. wt.) of *Clerodendron inerme* on 60th day after salt treatment.

RESULTS

Salinity induced biochemical responses

Amino acid

The results on the effect of NaCl salinity on the free amino acid are presented in Figure 1. The amino acids content of the leaf, stem and root decreased with increasing NaCl concentrations up to 200 mM and the higher concentrations showed a gradual increase up to 500 mM NaCl. Above 500 mM NaCl concentration, the cuttings did not survive. However, the highest value obtained in the leaf at 500 mM NaCl was 17.09% less than that of control. A similar trend was also seen in the stem and root tissues. At all concentrations, the root showed lower levels of amino acids when compared to those of leaf and stem.

Sugars

Total sugar content decreased in the leaf, stem and root with increasing NaCl up to 200 mM and at higher concentrations, salinity gradually increased the total sugar content up to 500 mM NaCl (Figure 2). Above 500 mM NaCl concentration, the cuttings did not survive. The leaves showed more total sugar content than the stem and root. The optimum concentration of 200 mM NaCl decreased the total sugar content and it was 9.90, 29.32 and 27.24% on 60th day respectively.

Protein

The effect of NaCl on the protein content in the leaf, stem and root are given in Figure 3. There was a gradual rise of protein in all the three tissues on all the sampling days with increasing NaCl up to 200 mM and at higher concentrations it steadily declined.

Proline

The effect of NaCl on the proline content in the leaf, stem and root are given in Figure 4. There was a gradual rise in the level of proline in all the three tissues on all the sampling days with increasing NaCl concentration up to 500 mM. Above 500 mM NaCl concentration, the cuttings did not survive. The leaf always had more proline than that of stem and root.

Glycinebetaine

The data on the effect of NaCl salinity on the glycinebetaine content of leaf, stem and root of *C. inerme* are given in Figure 5. There was a considerable increase in the accumulation of glycinebetaine with increasing salinity up to 500 mM and the increase was 60.26, 66.54 and 62.39% higher when compared to that of control on 60th day.

Chlorophyll

Sodium chloride treatment stimulated the chlorophyll synthesis in the leaves (Figure 6). An increasing trend in chlorophyll content of the leaf was noticed with increasing NaCl concentration up to 200 mM; thereafter it declined steadily. The maximum accumulation of total chlorophyll synthesis was recorded at 200 mM and this was 26.58% increase over that of control on 60th day after salt

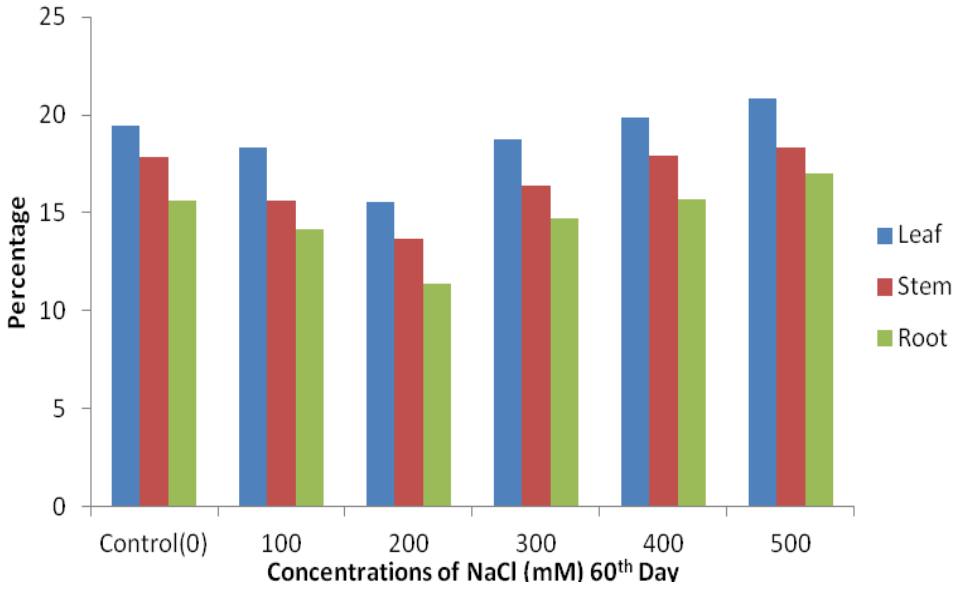

Figure 2. Effect of NaCl on Sugar content (mg/g fr. wt.) of *Clerodendron inerme* on 60th day after salt treatment.

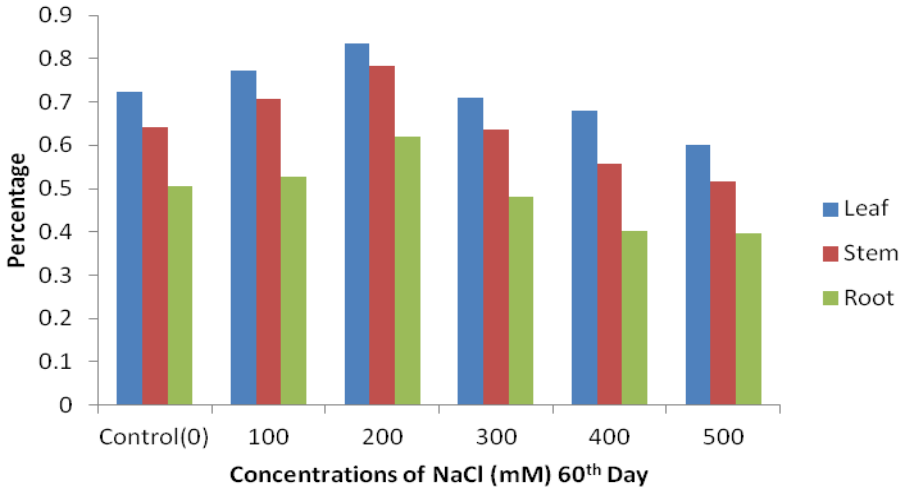

Figure 3. Effect of NaCl on Protein content (mg/g fr. wt.) of *Clerodendron inerme* on 60th day after salt treatment.

treatment. The chlorophyll 'a' was always higher than that of chlorophyll 'b' at all concentrations on all the sampling days. The chlorophyll a/b ratio was more than 1.

DISCUSSION

Amino acid

The total free amino acid content was found to decrease gradually with increasing concentrations of NaCl treatment up to 200 mM. Further increase of external NaCl was found to increase the free amino acid accumulation. Greater accumulation of amino acids was also observed in halophytic plants of *Aeluropus logopoides* and *Sporobolus madraspatanus* in response to increased seawater salinity in growth medium (Joshi et al., 1996; Joshi and Misra, 2000).

Sodium chloride stress increased the total amino acid and proline contents in all parts of the seedlings. The accumulation of free amino acids in salt stressed plants may be due to a reduction in the incorporation and conversion of amino acid into protein as observed by Hurkman and Tanaka (1987). Similar observations were

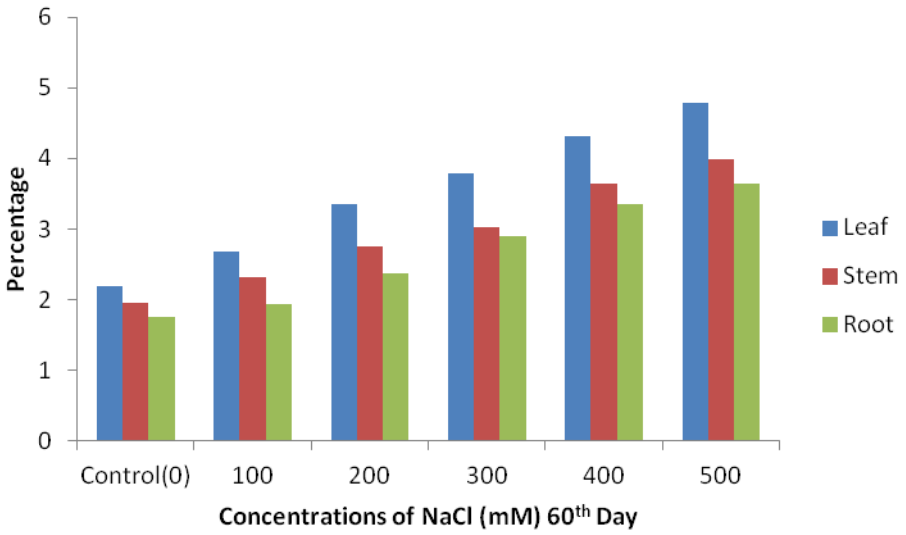

Figure 4. Effect of NaCl on Proline content (mg/g fr. wt.) of *Clerodendron inerme* on 60th day after salt treatment.

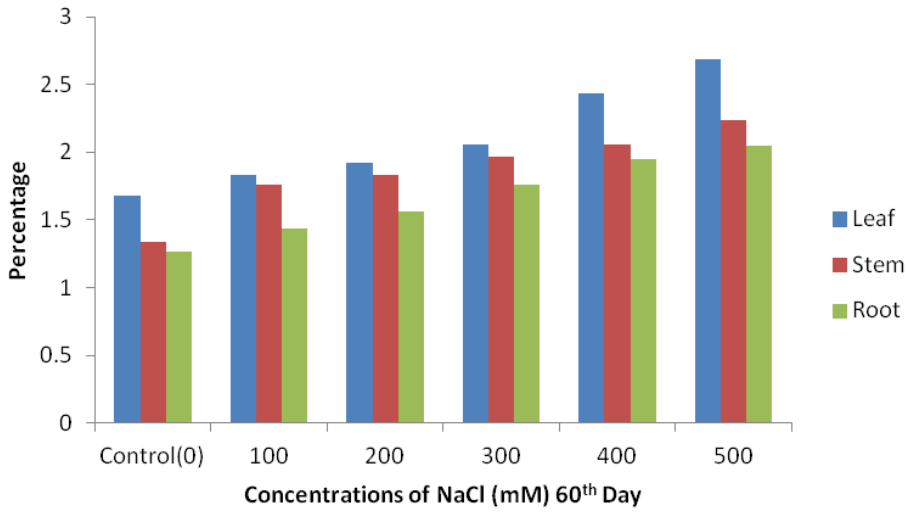

Figure 5. Effect of NaCl on Glycinebetaine content (mg/g fr. wt.) of *Clerodendron inerme* on 60th day after salt treatment.

made in *Arachis hypogeal* (Girija et al., 2002) and in *Sorghum* (Azooz et al., 2004). The amino acid is considered as one of the compatible solutes that accumulate in the cells and maintains the osmotic balance between the cells and the outer environment (Kim et al., 2001; Jain et al., 2001). The highest free amino acid accumulation was found in the case of the forest – sensitive *Triticum monococcum* (Simon-Sarkadi et al., 2001 and *Helianthus annuus* (Manivannan et al., 2008).

The total amino nitrogen pool of *Disphyma australe* increased as salinity increased to 500 mM NaCl (Neales and Sharkey, 1981). Sodium chloride salinity decreased the amino acid pool in *Rhizophora apiculata* and *Avicennia marina* (Rajendran and Kathiresan, 2000) and *Aegiceras corniculatum* (Parida et al., 2004). Under higher salinities, there was a decline in aspartic and glutamic acid content and an increase in proline in *Suaeda nudiflora* (Joshi and Iyengar, 1987).

Sugars

Sodium chloride salinity levels in *C. inerme* increased the starch content up to 200 mM, but decreased the total sugar content of the leaf, stem and root. On the other

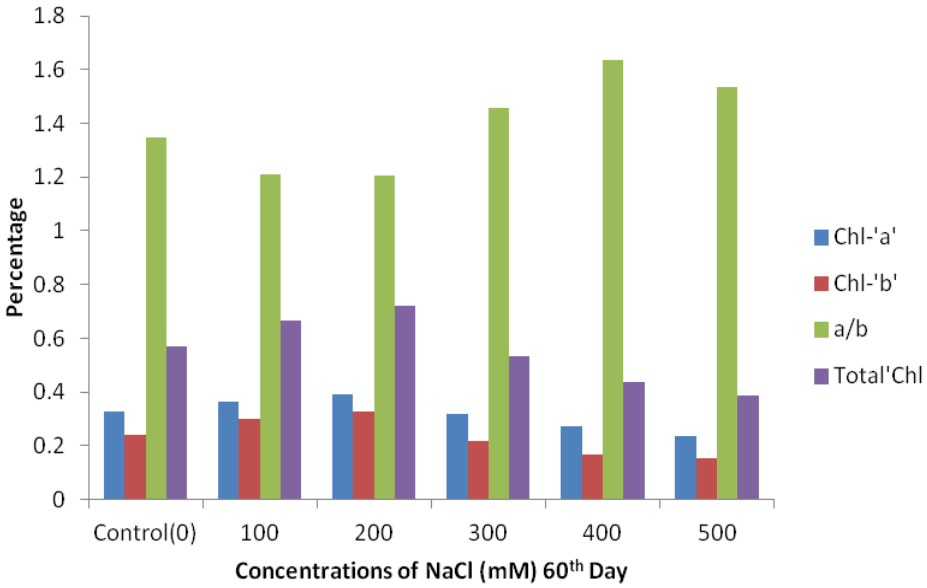

Figure 6. Effect of NaCl on Chlorophyll 'a', Chlorophyll 'b', total Chlorophyll a/b ratio (mg/g fr. wt.) content of *Clerodendron inerme* on 60th day after salt treatment.

hand, a decrease in the starch content and increase in total sugar content were observed after treatments with 500 mM NaCl.

Sugars are source of energy and carbons needed for adaptive and /or defensive responses of stresses. In addition, sugars such as raffinose and sucrose are indicated to have important roles in protecting cells from water stress; they are solutes available for osmoregulation or function as protectants of molecules and membranes (Bray, 1997).

Starch also accumulated in water treated cotyledons. Sucrose is considered to be the primary substrate for starch synthesis (Duffus and Duffus, 1984). It has been reported that the concentrations of sucrose and starch increase in excised and illuminated leaves of egg plants (Claussen et al., 1985). It is also known that starch content increases under the conditions where sucrose content is increased (Nakamua et al., 1991).

An increasing sugar content and corresponding decrease in the starch at higher salinities have been reported in several halophytes (Prado et al., 2000; Joshi et al., 2002; Ashraf and Harris, 2004). An increase in soluble carbohydrate content, principally sucrose in both monocotyledons and dicotyledons has been associated with an adaptation to saline conditions among higher halophytes (Wang et al., 1996). The increase in starch content and decrease in total sugar content can be attributed to the role of sodium to a certain level on stomatal opening (Eshel et al., 1974). Potassium ions may also play an important role in photosynthesis and starch metabolism (Wyn Jones et al., 1979). The increase in starch may be due to increase in the nitrogen content which plays an important role in photosynthesis (Cook and Evans, 1983).

Protein

The changes in soluble protein showed a reverse trend to that of free amino acids implying that the increase in protein content may be at the expense of the amino acids and that the salinity changes influenced the inter conversion of these compounds. Similar findings were observed in various halophytic species such as *S. madraspatanus (Joshi* and Misra, 2000) and *Heleochola setulosa* (Joshi et al., 2002).

In halophytes, the protein content increased with increasing concentrations such as *Atriplex satidea* (Flowers and Dalmond, 1992), and *Heleochola setulosa* (Joshi et al., 2002) and *Thellungiella halophila* (M'rah et al., 2006). In general, the protein content increased with increasing concentration up to an optimal level. Beyond the optimum level, the protein content decreased in *Phalaris arundinaceae* (Maeda et al., 1995), *Sesuvium portulacastrum* (Venkatesalu et al., 1994), *Ceriopsrox burghiana* (Rajesh et al., 1999) and *H. annuus* (Manivannan et al., 2008).

Protein content in the tissues of many plants declined under drought or salinity stress, because of proteolysis and decreased protein synthesis (Joshi and Misra, 2000). The marginal change in the protein content and protein profile, *A. corniculatum* suggests that NaCl exposure affects protein synthesis or proteolysis minimally in this plant. Several reports are highly decreased protein contents of leaves in glycophytes (Alamgir and Ali, 1999; Gadallah, 1999; Wang and Nil, 2000) even in a non-

secreting mangrove *Bruguiera parviflora* (Parida et al., 2002) in response to salinity. Proteins may be synthesized in response to salt stress or may be present constituently at low concentration and increase when plants are exposed to salt stress (Pareek et al., 1997; Bartles and Sunkar, 2005).

Proline

The accumulation of proline was more in the leaf tissues than in the stem or root tissues of NaCl treated plants. The maximum accumulation of proline was observed at 500 mM concentration. A positive correlation existed between the proline content and salinity treatments. Proline constitutes a major portion of the amino acid pool in different halophytic angiosperms (Treichel, 1975). Among all the amino acids, proline is the most stable and less toxic for cell growth and is more resistant for oxidative acid hydrolysis in plants subjected to stresses (Palfi et al., 1974).

The actual role of proline accumulation remains unclear (Rhodes et al., 1999) but it has been speculated that it can serve as an osmoprotectant (Pollard and Wyn-Jones, 1979), a protector of enzyme denaturation (Paleg et al., 1984), as stabilizer of macromolecules or molecular assemblies (Schwab and Gaff, 1990) a reservoir of nitrogen and carbon sources (Fukutaku and Yamada, 1984). Amino acid proline is known to occur widely in higher plants and normally accumulates in large quantities in response to environmental stresses (Kavikishore et al., 2005). In addition to its role as an osmolyte for water economy. Proline helps stabilize sub cellular structures (e.g membranes and proteins), scavenge free radicals and buffer cellular redox potential under stress conditions (Ashraf and Orooj, 2006). Proline accumulation appears as a consequence of a disturbance of cell homoeostatic and /or of an increase in the use of photosynthesis products for proline biosynthesis at the expense of plant growth (Ghars et al., 2007). Recent studies indicate that adaptation to salinity is closely associated with proline accumulation. A significant increase in proline content was found only at high salinity (Wang et al., 2006).

Increased proline content with increasing salinity has been reported in *S. portulacastrum* (Venkatesalu et al., 1994), *Atriplex griffithii* (Khan et al., 2000), *Bruguiera gymnorrhiza* (Takemura et al., 2000) and *A. corniculatum* (Manikandan and Venkatesan, 2004) and *S. portulacastrum* (Slama et al., 2008).

Glycinebetaine

The substantial increase in the glycinebetaine content was noticed with increasing NaCl concentrations up to 500 mM. The accumulation was comparatively more in the leaves. Glycinebetaine is considered to be a compatible solute in salt tolerant plants and it occurs primarily in the cytoplasm (Gorham and Wyn Jones, 1983). Glycinebetaine protects the photo system II (PS II) complex by stabilizing the association of the extrinsic PS II complex proteins in the presence of salt (Murata et al., 1992). A positive relationship between salt concentrations and accumulation of glycinebetaine was reported for a number of halophytes (Rhodes and Hanson, 1993; Khan et al., 2000).

Mangroves store high concentrations of proline and glycinebetaine in their leaves (Michael et al., 2003). In higher plants, the pathway of glycinebetaine synthesis is short and straightforward, choline to betaine dehydrogenate (BADH) convert this to glycinbetaine (Burnet et al., 1995).

Gorham (1995) reported the accumulation of glycinebetaine as an osmoticum in the cytoplasm when plants were exposed to increasing salinity. It is hypothesized that plants partition Na^+ and Cl^- in cell vacuoles and that glycinebetaine serves as a balancing osmoticum in the cytoplasm. Glycinebetaine is a compatible solute and this suggested that salt probably appears to be concentrated in vacuole and glycinebetaine accumulated in the cytoplasm (Takemura et al., 2000).

Chlorophyll

Sodium chloride salinity stimulated chlorophyll synthesis up to optimum concentration of 200 mM and at higher concentrations, the chlorophyll content decreased gradually. The maximum chlorophyll synthesis was observed in halophytes grown in natural saline soil when compared to control. These results suggested a positive effect of NaCl salinity on chlorophyll synthesis in the halophytes such *as S. protulacstrum* (Venkatesalu and Chellappan, 1993), *Bruguiera cylindrical* (Oswin et al., 1994) and *R. apiculata* (Oswin et al., 1994); Chlorophyll ‘a’ to ‘b’ ratio increased with increasing NaCl concentrations in *Sesuvium* (Ramani et al., 2006).

Similar results have been reported for other halophytes that increased the chlorophyll content with increasing salinity up to an optimal level; *Rhizophora mangle* (Warner and Stelzer, 1990), *Ipomoea pes-caprae* (Venkatesan et al., 1995), *Flaveria trinervia* (Apel et al., 1995) and *C. burghiana* (Rajesh et al., 1998).

Decrease of chlorophyll is mainly attributed to the destruction of chlorophyll ‘a’ which is considered to be more sensitive to salinity than chlorophyll ‘b’ (Singh and Dubey, 1995). The salt induced weakening of protein-pigment-lipid complexes or enhanced activity of chlorophylls (Rao and Rao, 1981). Decrease in the chlorophyll content under different salinity levels has been reported in a number of halophytes as well as crop species like *A corniculatum* (Shindle and Bhosale, 1985),

lemon leaves (Nieves et al., 1991), mulberry leaves (Ramanjulu et al., 1993) and rice seedlings (Singh and Dubey, 1995).

Conclusion

The present study shows that *C. inerme* is a moderately salt tolerant species. Sodium chloride salinity stimulated its growth, ion and mineral constituents, organic constituents and certain key enzymes up to the optimum concentration of 200 mM NaCl. Hence, it is concluded that this species could be recommended for cultivation in salt affected soils to reduce the soil salinity level.

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Conflict of Interests

The authors have not declared any conflict of interests

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Hybrid lilies under bulb removal stress

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The effect of bulb removal stress on vegetative and flower development of four hybrid lilies at different growth stages and their tolerance to this stress were investigated in this experiment. The tested hybrids were "Royal show" (LA hybrid), "White heaven" (L. longiflorum hybrid), "Sorbonne" and "Premium blond" (Oriental hybrids), four treatments included the bulbs were not removed (control) or removed two, four and eight weeks after planting weeks after planting (WAP) for all cultivars. The results showed that the bulb removal stress had adverse effect on vegetative and flower development of lilies, but the degree of this effect was dependent on the date of bulb removal. It was decreased as the period between planting and bulb removal was increased. Therefore, this stress effect was high when the bulb was removed two weeks after planting (WAP) while it was low when the bulb was removed eight WAP. Thus, the plants at different growth stages have different tolerance levels against this stress and they can survive and successfully complete the life cycle even without their bulbs when these bulbs were removed at late growth stage. The results also showed that the tested cultivars exhibited different response and tolerance to this stress. However, the "Royal show" cultivar was the faster in growth, earlier for flowering and more tolerant with better adapted to bulb removal stress compared to other hybrids.

Key words: Hybrid lilies, vegetative and flower development, bulb removal stress**,** growth stage.

INTRODUCTION

Lilies are the most important cut flower in the flower market worldwide, therefore the hybridization continuously produce new cultivars by genetic crossings between lily species, these hybrids have a great commercial ornamental value in floriculture industry and can be classified into main groups: Asiatic hybrids, LA hybrids (they are a cross between *L. longiflorum* and Asiatic lily), Oriental hybrids and longiflorium hybrids *(L. longiflorum*), OT hybrids (they are a cross between Oriental and Trumpet lilies) and LO hybrid (they are a cross between *L. longiflorum* and Oriental lilies). These groups have many things in common but there are some differences between them, some related to their morphological, anatomical structures and developmental patterns, while others related to their growing and environmental conditions (Roh, 2011; Grassotti et al., 2011; van Tuyl and Arens, 2011).

In Lilium, bulb represent highly specialized storage

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organ which plays a vital role in the growth and development of plant and it is essential for replication and for survival in adverse environmental conditions. Several studies were carried out to investigate the relationship between the bulb as source and flower as sink; their results confirmed that the flower is considered as primary sink utilizes and consumes the assimilates which received from two sources: bulb scales and current photosynthesis of bottom leaves. Whereas, the role and function of bulb are greatly different at different growth and development stages, it serves as main source in early development stage to supply carbohydrate reserves to the shoots and flower buds, after that and before anthesis it becomes as combination of sink and source, consequently both bulb and flower are as sink at anthesis, later bulb becomes the main sink to receive and store carbohydrate reserves for next growth season (Addai et al., 2011; Addai, 2010; Wu et al., 2012a, b).

It believe that the approach of organ removal from plant is a useful tool for more investigating about the role of this organ in growth and development of the plant, therefore multiple experiments used flower buds, leaves, bulb scales and bulb as experimental material for this approach (Asker, 2012; Addai, 2010; Leclerc et al., 2005; Wang et al., 1992). It is well known that the plants are considered to be under stress when they are subjected to unfavorable growth conditions such as drought, salinity, heat stress, low light and more other kinds of stresses such as defoliation stress, deflowering stress. The stress has negatively effect on plant growth and yield of crops and caused a number of metabolic and developmental changes, in another side the plants under stress can perform some adaptation in different levels and in different defense mechanisms and ways such as behavioral, morphological, anatomical, physiological, and biochemical (Erik and David, 1996).

The purpose of the present study is to investigate the effect of bulb removal stress on vegetative growth and flower development of four hybrid lilies at different growth stages and to evaluate their response and tolerance to this stress.

MATERIALS AND METHODS

This experiment was conducted in the nursery of Floriculture Unit, Baghdad University, Iraq in October 2012 to January of 2013. vernalized bulbs of four lily hybrids including "Royal show" represents LA hybrids group, "White heaven", represents L. longiflorum hybrid group , "Sorbonne" and "Premium blond" represent oriental hybrids group (10 to 14 cm in circumference) were imported from the Netherlands. The bulbs were planted inside the plastic house of the nursery in cultivation beds containing peat-moss (peat-moss was obtained from Estonia; type H2-4,) and contains N: P: K- 14:16:18 fertilizer, lime, with pH value of (5.9). Planting was at 10 cm depth with 20 (cm) apart to promote development of stem roots, and the irrigation was manually. To remove the bulb from the plant, the stem was cut off carefully above the nose of the bulb without any effect to stem roots .The plant was re-planted again immediately after the bulb was removed; the dates of bulb removal were 2, 4 and 8 WAP (weeks after planting). The control treatment consisted of plants whose bulbs were not removed.

At blooming time, data of plant height (cm), number of flowers per plant and flower diameter (cm), number and weight (g) of leaves per plant were collected. Weeks taken for flower buds emergence at visible stage and weeks taken for first flower emergence at flowering time were noted as bud appearance time and as bloom time respectively.

This experiment was arranged in a completely randomized block design (CR-BD) and sixteen treatments used each treatment consisted of three replicates, and each replication consisted of 8 bulbs. Data were subjected to analysis of variance using Statistical analysis system (SAS) program and the mean separation was performed using Duncan's multiple range test at the 5% level of significance.

RESULTS

Plant height

The results in (Table 1) showed that the plant height (cm) at flowering was different as dependent on bulb removal date and cultivars. It varied from 12.58 to 80.58 cm. However, it was higher significantly in control treatment and lower in two weeks treatment compared to others in all cultivars. Plant height of four hybrids of lilies showed significant differences and the "Royal show" cultivar had the tallest plants

Leaves number and weight

The results (Tables 2 and 3) showed that the number and weight (g) of leaves per plant at flowering was different as dependent on bulb removal date and cultivars. It varied from 20.92 to 68.17 per plant (number), and from 4.59 to 52.33 per plant (weight).However, the number and weight (g) of leaves was higher significantly in control treatment and lower in two weeks treatment compared to other treatments. The number and weight of leaves differed significantly among the hybrids of lilies and the LA hybrid lily "Royal show" showed the highest number and weight of leaves.

Flowers number

The flower number per plant showed significant differences as dependent on bulb removal date and cultivars (Table 4). It varied from 0.0 to 4 per plant. However, it was higher significantly in control and eight weeks treatments compared to others, and the flower buds formation was inhibited as a result of two weeks bulb removal treatments in all cultivars.

The number of flowers per plant differed significantly among the hybrids of lilies and the LA hybrid lily "Royal show" showed more flowers per plant compared to other cultivars.

Table 1. Effect of bulb removal date on the plant height (cm) in hybrid lilies.

Time of bulb removal		Plant height (cm)				
		Cultivars				
Weeks after planting		**Royal show**	**White heaven**	**Premium blond**	**Sorbonne**	**Mean**
Two		27.38	12.58	28.58	24.00	23.14
Four		41.33	21.42	38.54	39.30	35.15
Eight		74.75	49.04	64.08	66.45	63.58
Control (bulb not removed		80.58	59.71	70.71	71.75	70.69
Mean		56.01	35.69	50.48	50.38	
LSD	Times		1.608			
	Cultivars		1.608			
	Time ×cultivar		3.216			

The mean separation was performed using Duncan's multiple range tests at the 5% level of significance.

Table 2. Effect of bulb removal date on the number of leaves per plant in hybrid lilies.

Time of bulb removal (weeks after planting)		No. of leaves				
		Cultivars				
		Royal show	**White heaven**	**Premium blond**	**Sorbonne**	**Mean**
Two		52.71	20.92	26.08	25.63	31.33
Four		55.58	29.33	34.38	30.88	37.54
Eight		66.46	31.21	34.88	31.04	40.89
Control (bulb not removed)		68.17	33.54	36.92	32.58	42.80
Mean		60.73	28.75	33.06	30.03	
LSD	Times		1.596			
	Cultivars		1.596			
	Time ×cultivar		3.192			

The mean separation was performed using Duncan's multiple range tests at the 5% level of significance.

Table 3. Effect of bulb removal date on the weight of leaves (g) per plant in hybrid lilies.

Time of bulb removal		No. of flowers				
		Cultivars				
Weeks after planting		**Royal show**	**White heaven**	**Premium blond**	**Sorbonne**	**Mean**
Two		10.83	4.59	5.88	8.00	7.32
Four		35.07	22.45	23.02	24.30	26.21
Eight		36.31	30.31	29.84	31.46	31.98
Control (bulb not removed)		52.33	37.08	36.10	35.99	40.37
Mean		33.63	23.61	23.71	24.94	
LSD	Times		0.515			
	Cultivars		0.515			
	Time ×cultivar		1.029			

The mean separation was performed using Duncan's multiple range tests at the 5% level of significance.

Flower diameter

The flower diameter (cm) was different as dependent on bulb removal date and cultivars (Table 5). It varied from 0.0 to 22.54 (cm) among the treatments. However, the plants of control and eight weeks treatments produced significantly larger flowers compared to the plants of other treatments. The diameter of flowers differed

Table 4. Effect of bulb removal date on the number of flowers per plant in hybrid lilies.

Time of bulb removal		Wt. of leaves (g)				
		Cultivars				
Weeks after planting		**Royal show**	**White heaven**	**Premium blond**	**Sorbonne**	**Mean**
Two		0.00	0.00	0.00	0.00	0.00
Four		3.50	0.00	2.00	2.50	2.00
Eight		3.83	1.00	2.58	3.75	2.79
Control (bulb not removed)		4.00	1.00	2.80	3.83	2.91
Mean		2.83	0.50	1.84	2.52	
LSD	Times		0.152			
	Cultivars		0.152			
	Time ×cultivar		0.304			

The mean separation was performed using Duncan's multiple range tests at the 5% level of significance.

Table 5. Effect of bulb removal date on flower diameter (cm) in hybrid lilies.

Time of bulb removal		Flower diameter (cm)				
		Cultivars				
Weeks after planting		**Royal show**	**White heaven**	**Premium blond**	**Sorbonne**	**Mean**
Two		0.00	0.00	0.00	0.00	0.00
Four		16.30	0.00	17.50	15.96	12.45
Eight		17.42	17.00	21.67	17.04	18.28
Control (bulb not removed)		18.63	17.50	22.54	21.38	20.01
Mean		13.09	8.63	15.43	13.59	
LSD	Times		0.221			
	Cultivars		0.221			
	Time ×cultivar		0.441			

The mean separation was performed using Duncan's multiple range tests at the 5% level of significance.

significantly among the tested hybrids of lilies. The flowers of Oriental hybrids "premium blond" and "Sorbonne" were larger than other cultivars.

DISCUSSION

The results indicated that the development of above-ground organs of plant was greatly affected by bulb removal stress which caused limited in vegetative growth and flower development and that probably due to the removal of bulb resulting in loss of the major source for carbohydrate reserves which caused the plant development processes to depend only on the assimilates received from current photosynthesis. But the degree of this stress effect varied among treatments depending on the growth stage at which the bulbs were removed and it was decreased as the period between planting and bulb removal was increased. Therefore this effect was high when the bulb was removed two WAP while it was low when the bulb was removed eight WAP and that probably due to this stress associated with the potential changes in the role of bulb in plant development during the whole life cycle of the plants. This could be explained, the tolerance of plant to bulb removal stress was lower at early stage of growth when the bulb was the main source to supply assimilates for development whereas it was higher at late growth stage when both bulb and leaves were serve as source or when leaves was as source and bulb was as sink (Addai et al., 2011; Addai, 2010; Wu et al., 2012a, b), therefore the plants can successfully complete the development processes even in the absence of their bulb at late growth stage.

The time of buds appearance at visible buds stage was different as dependent on cultivars. LA hybrid lily took the shortest period (5 weeks) while oriental hybrid lilies took the longest period (8 weeks). The flower buds did not appeared in all plants of two weeks treatment. The time (weeks) from planting to flowering was also different among the hybrid lilies. LA hybrid lily " Royal show " took the shortest period (11 weeks) while oriental hybrid lilies took the longest period (15 weeks), thus, the LA hybrid

lily "Royal show" showed faster in growth, earlier in flowering and also was more tolerant and better adapted to bulb removal stress compared to other hybrids whereas oriental hybrid lily bloomed later than other types of Lilium with larger flowers.

These results indicated that the lily plants under bulb removal stress have a potential defense response and they can survive without their bulb, but that dependent on growth stages of the plants when the bulbs were removed and on cultivars.

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Full Length Research Paper

The status of livestock technologies and services in the Southern Maasai rangelands of Kenya

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This study was carried out in Mashuru district, Kajiado County in the Southern Maasai rangelands of Kenya to assess the status of livestock technologies and services. Data was collected using a survey of 380 households, participatory stakeholder workshops, five focus groups with pastoralists, and key informant interviews. Analysis was done using frequency counts, percentages and chi square test. The findings of this study revealed that access to livestock technologies and services was hampered by institutional (77%), technological (12%), environmental (9%) and economic (2%) factors. Inadequate government staff, long distances to service providers and weak institutional linkages were the most common problems encountered by 27, 20 and 17% of pastoralists respectively. Technologies perceived to be important included: Availability of water and water harvesting technologies (52%); pastures (28%); vaccines and drugs (8%); dual purpose breeding stock for milk and meat production adapted to dry climatic conditions (4%); market infrastructure and information (4%); management skills (3%), and small equipment (1%). In view of problems encountered in accessing livestock services, Maasai pastoralists preferred the establishment of one-stop-shop centres stocked with priority inputs and technologies (P<0.05). The willingness of pastoralists (65%) to pay for this service should attract public-private partnerships to support livestock productivity in rangelands.

Key words: Livestock technologies and services, pastoralists, Maasai rangelands, multi-institutional linkages.

INTRODUCTION

There is great potential for improvement of livestock productivity in Arid and Semi-Arid Lands (ASALS) in Sub Saharan Africa and Kenya in particular, yet this potential has not been fully realized (Adugna and Aster, 2007), mainly due to divergent research, extension and other development approaches, which are largely uncoordinated (Omore et al., 2009) as well as constraints associated with inadequate feed resources, disease control strategies and poor infrastructure (Mgheni et al., 1992).

Following liberalization policies of 1990s in which most African governments reduced involvement in provision of free livestock services (Den Haan and Bekure, 1991), the delivery of livestock services in Sub Saharan Africa, including Kenya, has seriously declined over the last two decades (Tambi and Maina, 1994). Consequently, the

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majority of pastoralists now rely more on drug manufacturers and other service providers for information which is often compartmentalized because it is given by different service providers dealing with different commodities. Given that most of Kenya's red meat is produced in ASALS, access to productivity enhancing technologies is of utmost importance. This study sought to make an assessment of the status of livestock technologies and services on the premise that supporting livestock keepers in pastoral areas to access necessary inputs and services has the potential to improve productivity and commercialization of livestock in the rangelands.

MATERIALS AND METHODS

Study area

Mashuru district lies at longitude 36.70° E and 37.50° E and latitude 1.50° S and 2.20° S. It occupies an area of 2192.6 km^2 with a population of 41 655 persons consisting of 20974 males and 20681 females, grouped into 8810 households with a population density of 17 inhabitants/ km^2 (District statistics report, 2010). The occupants of the district are predominantly Maasai pastoralists keeping cattle, goats, and sheep, under extensive and ranching production systems. It is a semi arid region in Agro ecological IV to VI characterized by low rainfall of less than 500 mm per annum and temperatures ranging from 24 to 37°C (Jaetzold et al., 2006). The low and often unreliable rainfall makes pastoralism the only suitable economic activity. The most dominant vegetation consist mainly of perennial grasses, shrubs and thorn trees.

Sample size, study variables and data collection methods

All pastoralists in the district (N = 8810) formed the population from which a sample size was determined using the formula by Kothari (2008): $n = N/ 1+N (e^2)$, where n is the required sample size, N = estimated study population and e = marginal error set at 5%. Quantitative and qualitative data were collected through a survey of 380 households, stakeholder workshops, five focus group discussions, ten key informant interviews and transect observations. The data collected included: livestock species kept by pastoralists and preferences, common diseases, important inputs and services, service provision by public and private sector, constraints related to access to inputs, preferred interventions and willingness to pay for services. Quantitative data was collected using a structured questionnaire administered to 380 households randomly selected from ten locations in the district (Kothari, 2008). Qualitative data was gathered through workshops, focus group discussions and interviews with community leaders and ministry of livestock staff purposively selected to provide a deeper understanding of the status of livestock technologies and services (Kumar, 1993; Mariner,and Paskin 2000; Kruger, 2002).

Data analysis

Data was entered in Statistical Package for Social scientists version 19 to produce frequency counts and percentages of various livestock technologies and services, while chi square test was used to analyse intervention options and willingness to pay (Kothari, 2008; Mugenda and Mugenda, 2003).

RESULTS

Livestock production

Table 1 shows the results of common livestock species kept. Cattle were the most important source of income, milk, meat as well as for payment of dowry. Goats and sheep were the next important species for income and meat, while donkeys were kept mainly for transport of water and firewood, mainly by women. Chicken were ranked last because they are regarded by most pastoralists as an enterprise for women and children.

Priority diseases

Priority diseases to livestock production as identified from focus group discussions and interviews and ranked through household survey are listed in the Table 2. Foot and Mouth Disease (FMD) and Contagious Caprine Pleuropneumonia (CCPP) were ranked as most important in cattle and goats respectively. Pastoralists associated their occurrence with introduction of new animals into the herd due to purchases, movements or interaction at watering points. Black quarter and Newcastle were priority diseases in sheep and local chicken respectively. Endemic diseases were mentioned as East Coast Fever in cattle and Foot rot in goats and sheep.

Inputs and services

Input and services perceived to be important are listed and ranked in Table 3. Among the pastoralists surveyed in the district, 52% (N = 198), 28% (N = 105), 8%, (N = 31) and 4% (N =17) mentioned water, pasture, vaccines and drugs, and availability of breeding stock / forage germplasm respectively as the most important livestock inputs.

Public versus private service providers

A comparison of the benefits from public vs. private service providers as perceived by pastoralists is shown in Table 4. The nearest service provider was the livestock owner himself who were perceived to be cheap and accessible, though not efficient. All the pastoralists buy drugs from agrovets and treat their own animals. Public service providers such as the extension department were neither accessible nor available when required though perceived to be efficient and gives advice.

Problems in accessing inputs and services

Problems encountered by pastoralists while accessing

Table 1. Livestock species kept in order of importance and preferences as perceived by pastoralists.

Livestock species	Frequency (f) (N=380)	Percentage	Ranking reasons for preference				
			1	2	3	4	5
Cattle	270	71.1	Income (136)	Milk (57)	Meat (38)	Dowry (25)	Hides(14)
Goats	51	13.4	Income (30)	Meat (9)	Milk (7)	Skin (5)	
Sheep	34	8.9	Income (20)	Meat (9)	Skin (5)		
Donkey	13	3.4	Transport (11)	Income(2)			
Chicken	12	3.2	Meat(8)	Income (4)			

Table 2. Important diseases to pastoralists.

Livestock species	Priority diseases in terms of impact on mortality, morbidity and loss of income								
	1	N	%	2	N	%	3	N	%
Cattle	FMD	236	62.2	Anthrax	103	27	ECF	41	10.8
Goats	CCPP	216	56.9	Black anthrax	89	23.5	Foot rot	75	19.6
Sheep	Black quarter	232	61	Foot rot	133	35	Enterotoximea	15	4
Chicken	New castle	253	66.7	Fowl pox	127	33.3			

FMD: Foot and Mouth Disease; ECF: East Coast Fever; CCPP: Contagious Caprine Pleuropneumonia; N: Number of respondents.

Table 3. Inputs and services perceived to be important by pastoralists.

Input / service	Frequency	Percentage
Water	198	52
Pasture	105	28
Vaccines and drugs	31	8
Germplasm: Breeding stock, forage species	17	4
Market information	14	4
Capacity building	10	3
Small equipment : spray pumps, syringes, buddizo	5	1
	N=380	100%

Table 4. Merits of public versus private sector service providers as perceived by pastoralists.

Merits	Public sector	Private sector			
	Government agencies	CAHW	NGO	Agro-vet shops	Self
Cheap	1	1	1	0	1
On time	0	1	0	0	1
Efficient	1	0	0	0	0
Available	0	1	0	1	1
Near to pastoralist	0	1	0	0	1
Gives advice	1	1	1	0	0
Accessibility	0	1	0	1	1
Better known	0	1	0	0	1
Quick to respond	0	1	0	0	1
Sub-total points	3	8	2	2	7
Total points	3			19	

1 = Yes; 0 = No; CAHW: Community Animal Health Workers; NGO: Non Governmental Organizations; Source: Stakeholder workshops and focus groups

Table 5. Problems encountered by pastoralists in accessing inputs / services.

Factor	Problem	Frequency	Percentage by factor	Percentage by problem
Institutional	Inadequate Government livestock service providers	102	27	77
	Long distance to livestock input service providers	77	20	
	Weak institutional linkages	65	17	
	Lack of feedback from previous projects	20	5	
	Government and donor funded project priorities contrast with community interests	10	3	
Technological	Inadequate infrastructure – roads, power, water	22	5	12
	Unavailability of cold chain for vaccine portability	25	7	
	Poor packaging: mismatch between quantity demanded and quantity sold	19	5	
Economic	High cost of drugs	7	2	2
Environmental	Recurrent drought	33	9	9
		N = 380	100%	100%

Table 6. Suggested interventions to address constraints to livestock technologies and services.

Intervention	Frequency	Percentage	Willingness to pay	
			Yes	No
Establish a one-stop-shop resource centre for inputs	247	65	160 (64.8%)	87 (35.2%)
Capacity building of pastoralists	79	21	61 (77.2%)	18 (22.8%)
Improve market facilities and development of livestock markets	38	10	4 (10.5)	34 (89.5)
Improve infrastructure especially roads and water	8	2	2 (25%)	6 (75%)
Employ and deploy more extension staff in ASALS	8	2	2 (25%)	6 (75%)
	N= 380	100		

livestock services are shown in Table 5. Institutional factors mainly inadequate government services, long distances to input providers and weak institutional linkages were identified as the common problems encountered by 27, 20 and 17% respectively of the pastoralists surveyed. Other pressing problems were identified as recurrent drought (9%), unavailability of cold chain for vaccine storage (7%) as well as inadequate infrastructure (5%) particularly roads, water and power. Government and donor priority contrasting with community interests was mentioned by 5% of the pastoralists.

Interventions

Interventions suggested by pastoralists to address constraints to accessing livestock technologies and services are shown in Table 6. Out of the 380 households surveyed, 247 prefer the establishment of a one-stop-shop-resource centre for inputs within the community, while 79 and 38 households respectively suggested capacity building of pastoralists and improvement of livestock marketing and facilities. On willingness to pay for inputs and services, 65% of respondents showed willingness to pay for a resource centre, while 21 and 10% would pay for capacity building and market facilities respectively. Only 2% of the households were willing to pay for employment of extension staff and construction key infrastructure such as roads.

DISCUSSION

Livestock production

The findings of this study showed that cattle are the most important livestock species kept mainly for income, milk, meat and dowry, while goats and sheep are kept for income, meat and skins. These results agree with those

found by Adugna and Aster (2007) in the pastoral production system of Southern Ethiopia. The sahiwal breed is dominant and is preferred due to its dual purpose traits of milk and beef production and adaptability to the dry climatic conditions. Contrary to popular opinion held by outsiders that the Maasai kept livestock for prestige and numbers, we did not find this mentioned as one of the objectives in all focus group discussions and survey throughout the district. These results agree with those obtained by Cossins (1985) in the Sahel region, who argued that pastoralists are not attached to unproductive animals as outsiders believe. Rather, it is the result of the environment and the multiple objectives for keeping livestock which determines the number of animals a family can keep.

Livestock diseases

Priority diseases as perceived by pastoralists in terms of morbidity, mortality and loss of incomes were: Foot and Mouth Disease (FMD) and Anthrax in cattle; Contagious Caprine Pleuropneumonia (CCPP) in goats; Black Quarter in sheep and New castle disease in chicken. Most of these diseases are transboundary animal diseases (TADs) caused by interaction of infected and healthy animals during extensive movements, communal watering or newly purchased animals in the herd. TADs have been known to be priority diseases in pastoral areas (Perry et al., 2005). However, there is little success in control strategies as the public veterinary service appears in these areas only when there is an epidemic. These diseases have far reaching economic and social consequences at household, community and national levels and hence control cannot be left to the private sector or pastoralists as a result of reduced state funding (Perry et al., 2005). Integration of pastoralists in management of these diseases is of utmost importance.

Inputs and services

Water, pasture, drugs and vaccines, breeding stock were ranked as most important inputs and limiting constraints to livestock production as perceived by 52, 28, 8 and 4% of the pastoralists respectively. Access to drugs and vaccines is particularly a challenge since service providers are found only in large towns. This result is consistent with the ministry of livestock reports which observe that there is low input use owing to poor distribution of input suppliers and challenges associated with infrastructure (GOK, 2008)

Public vs. private service providers

The findings of this study show that the Maasai pastoralists are mainly served by the private sector. This is because they are readily available and accessible. Though the public sector is not visible on the ground, they are perceived to be more competent and have better facilities compared to private sector. However, Mugunieri et al. (2004) compared productivity of livestock herds among farmers who utilized the services of community-based animal health workers and veterinarians and found that they were not significantly different. Hence there is need for linkages with private sector for efficient and effective delivery of services.

Factors influencing access to inputs and intervention strategy

The main factors influencing access to inputs and services identified by pastoralists and other stakeholders in the area are predominantly institutional (77%) rather than technological (12%). These included inadequate government extension staff long distances to service providers, weak institutional linkages and inadequate infrastructure. Priority interventions suggested addressing the problem of inputs and technology availability and accessibility were establishment of a one- stop-shop for inputs, capacity building of pastoralists improvement of market facilities, and road and water infrastructures. The majority of pastoralists (65%) expressed willingness to pay for the inputs centre and capacity building ($p<0.05$). However they were not willing to pay for improvement of roads and water since they perceived them as public services, even though these were important infrastructure in rangelands. This finding on pastoralists preferred intervention concurs with Omiti and Irungu (2002) who observed that most interventions in the Kenyan pastoral areas have been intermittent and sporadic in nature, often in response to crises such as drought and famine.

Conclusion

The findings of this study indicate that access to livestock technologies and services in Mashuru district in the Southern rangelands of Kenya are hampered by institutional rather than technological factors, and need to be strengthened through effective extension, stakeholder linkages and improved infrastructure. In view of problems encountered in accessing livestock inputs and technologies, pastoralists prefer the establishment of one-stop-shop centres stocked with priority inputs and key information pertaining to livestock production, health and markets. The willingness of the majority of pastoralists to pay for this service should attract public-private partnerships to support livestock productivity in rangelands. Towards this endeavor is the implementation of appropriate models for the provision of livestock services that take into account local contexts in many

areas especially where service markets have not worked.

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Abbreviations: **ASALS,** Arid and semi arid lands; **FMD,** Foot and mouth disease; **CCPP,** Contagious Caprine Pleuropneumonia; **CAHW,** Community Animal Health Worker; **NGO,** Non Governmental Organization.

Conflict of Interests

The authors have not declared any conflict of interests

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Nitrogen use efficiency by selected NERICA varieties in Burkina Faso

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A field experiment was carried out in the 2005 and 2006 wet seasons in Bagré, Burkina Faso, to assess the differences in paddy yield and nitrogen (N) utilization of the New Rice for Africa (NERICA) lowland varieties. The test consists of a split-plot design with four replications. The main plots were represented by four NERICAs (NERICA L 41, NERICA L 60, NERICA L 20, and NERICA L 19) and one control (4418). Subplots were constituted with five rates of nitrogen fertilizer (0, 40, 80, 120 and 160 kg N ha^{-1}). Significant differences (P<0.001) among varieties were observed in paddy yield and nitrogen uptake. Without nitrogen application (0N), NERICAs insure a good grain yield compared to the control (4418). The N-use efficient varieties that produced high paddy yield at both low and high levels of N were NERICA L 41, NERICA L 20 and NERICA L 19. NERICA L 60 that is not significantly different to the control (4418) appears less efficient as compared to the three other NERICAs.

Key words: Nitrogen uptake, fertilizer-N use efficiency, paddy yield, irrigated rice.

INTRODUCTION

Rice is developing as a major staple food crop of Burkina Faso. Demand has grown at an annual rate of 3% between 1973 and 1992 compared with an annual population growth rate of 2.9%, which can be explained by changing consumer preferences (Africa Rice Center, 2008). The annual per capita consumption increased from 18.2 kg in 1999 to 21 kg in 2008 (MAHRH, 2010). It reached 50 kg per person in urban centers in Ouagadougou and Bobo-Dioulasso. Domestic production in paddy rice was 195,102 tons in 2008, 249,063 tons in 2011 and 319,390 tons in 2013 (CEFCOD, 2013). Currently, in-country production covers 42% of the demand estimated at 255 176 tons of white rice, and 58% is met from imports (CEFCOD, 2013). While irrigated lowlands comprise only about 23% of the total rice area, this system is characterized by considerably higher yields and contributes about 53% to national rice production (INERA-DGPER, 2010).

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The lowland rice cropping system is the traditional shape of most practiced rice cropping system in Burkina Faso. This type of rice cropping system takes the most part of areas and combines the rainfed and irrigated systems. It occupies about 90% of the rice areas of Burkina Faso, and contributes for 95% to the country's rice production (INERA-DGPER, 2010). The traditional cultivars that take the most part of valley bottoms are more and more in way of disappearance because of their cycle less adapted to the reduction of the rainfall (Sié and Dakouo, 1998).

The Africa Rice Center and partners have developed a family of 60 interspecific hybrids adapted to lowland growth conditions by crossing Asian rice (*Oryza sativa*) and African rice (*Oryza glaberrima*). These genotypes have been named lowland NERICAs (NERICA-L). Their main breeding objectives were yield potential, grain quality, broad adaptation to diverse lowlands in the region, and resistance against Rice Yellow Mottle Virus and African Gall Midge (Sié et al., 1998, 2004, 2008; Sié and Dakouo, 1998). Rodenburg et al. (2006) provided complete information on pedigrees and backcross parents of the lowland NERICA cultivars.

However, breeding program aiming to improve nitrogen use efficiency is still limited. Soil fertility, fertilizer use and crop response to nutrient inputs may vary widely among regions and/or rice fields within smaller irrigated and rainfed rice environments, and also from season to season in the same field (Adhikari et al., 1999; Olk et al., 1999; Dobermann and Cassman, 2002; Dobermann et al. 1998; 2003).

Nitrogen is the most yield-limiting nutrient in rice cropping systems worldwide (Mikkelsen, 1987; Cassman et al., 1996a, b; Jiang et al., 2004) and because of the many pathways for the nitrogen loss, especially in the alternating wet/dry cycles of rice systems; it is also the most difficult nutrient to manage (Mikkelsen, 1987; Buresh et al., 1989).

Beside the importance of the nitrogen on the irrigated rice productivity, the relation between N supply (by fertilization) and indigenous N (from soil) is in general weak (Cassman et al., 1996c); so a weak efficiency of N use is observed (Olk et al., 1999; Wopereis et al., 1999). The losses of nitrogen coming from fertilizers are estimated from 20 to 70% (Cassman et al., 1993; Wopereis et al., 1999). These authors conclude that the contributions of N fertilizer that do not take into account the soil nutrient capacity contribute to significant losses by denitrification and by ammoniac volatilization. Fertilizers represent about 30% of the total production costs and all practices that limit N losses present economic advantages (Donovan et al., 1999). Since the cost of fertilizer is increasing and resource-poor farmers in the fragile environments cannot afford to buy fertilizer, identification or development of rice genotypes that are adapted to non-fertilized conditions and have high responsiveness to nutrient inputs would be an attractive and cost-effective approach (Ladha et al., 1998; Saito and Futakuchi, 2009). Genotypic difference in response to applied fertilizer has been reported repeatedly in the lowlands in Asia (Ladha et al., 1998; Inthapanya et al., 2000a; Haefele et al., 2008, Saito et al., 2010a). However, similar information for West African, like Burkina Faso conditions is scarce. Because of the high potential for N loss, N use efficiency in rice trends to be lower in comparison with other major crops (Keeney and Sahrawat, 1986). The identification of the factors that determine grain yield and nitrogen utilization in rice production systems is necessary to optimize their productivity and reduce the pollution risk for the environment (Koutroubas and Ntanos, 2003). Reduction of N loss would increase both N in the soil, fertilizer-N use efficiency, and reduce the environmental costs associated with denitrification and leaching of NO_3 (George et al., 1993).

The objectives of the study were to evaluate the response of rice varieties to nitrogen fertilizer. More specifically, the study intend (i) to assess the varietal differences in the efficiency of indigenous nitrogen use, (ii) to assess the varietal response to N fertilizer, (iii) to determine the efficiency, the inefficiency and the low responses of varieties to nitrogen supply and (iv) to determine the paddy yield and nitrogen uptake.

MATERIALS AND METHODS

Description of the study area

The study was conducted in the rice plain of Bagré village (11°30' N, 0°25' W) located in the eastern part of Burkina Faso, West Africa. The climate is typical for the agro ecological zone of the Sudan savanna with rainy season occurring from July to October, followed by a cold and dry season from November to February, and a hot dry season from March to June. Average annual rainfall is 850 mm $year^{-1}$ and minimum air temperature below 15°C occur in the cold dry season, and maximum temperatures above 39°C occur in the hot dry season (BEGE, 2008).

Soil types

Soils of the scheme are developed in alluvial sediments of Quaternary age. According to FAO classification (FAO, 1988), soils of the irrigated scheme (600 ha on the left bank of the Nakanbe river) were classified as Gleysols and dystric Fluvisols (62% of total area). Soil depth was on average between 0.4 to 1.2 m. Physical and chemical characteristics of experimental site are presented in Table 1.

Experimental design and crop management

The experimental design is a split-plot with four replications. Five increasing doses of nitrogen (0, 40, 80, 120 and 160 N kg ha^{-1}) constitute the sub-plot treatments. The main plots are represented by five rice varieties. Four of them are interspecific varieties (*O. glaberrima x O. sativa*) selected on the basis of their agronomic performances after participatory varietal selection (PVS) (Sié et al., 2004). These varieties are NERICA L 19, NERICA L 20, NERICA L 41 and NERICA L 60. The control variety (4418) is one of the more used by Bagré's farmers. Each variety is transplanted in a plot of 6

Table 1. Application timing of fertilizers.

Fertilizers	Application timing	
	Active tillering	Panicle initiation
0 N (kg N ha^{-1})	0	0
40 N (kg N ha^{-1})	40	0
80 N (kg N ha^{-1})	40	40
120 N (kg N ha^{-1})	60	60
160 N (kg N ha^{-1})	80	80

Table 2. Physical and chemical characteristics of soil.

Types of compound	Characteristics and chemical composition	
	0-20 cm depth	
Granulometric analyses	Clay (< 2 µm), %	17.25
	Fine silts (2-20 µm), %	6.75
	Coarse silts (20-50 µm), %	11.15
	Fine sands (50-200 µm), %	26.53
	Coarse sands (200-2000 µm), %	38.33
Bulk density	(g cm^{-3})	1.69
Organic matter	Total organic carbon, %	0.74
	Total nitrogen, %	0.06
	Carbon / Nitrogen	13
Potassium	Total %	0.01
Phosphorus	Phosphorus-Bray, mg kg^{-1} of soil	2.10
	Total Phosphorus, mg kg^{-1} of soil	103
Exchangeable cations	Calcium (Ca^{2+}), cmol kg^{-1} of soil	4.00
	Magnesium (Mg^{2+}), cmol kg^{-1} of soil	2.80
	Potassium (K^{+}), cmol $kg^{-1}$of soil	0.12
	Sodium (Na^{+}), cmol $kg^{-1}$of soil	0.16
	Cation exchange capacity (CEC), cmol kg^{-1} of soil	7.70
	Saturation %	91.00
Soil reaction	pH H_2O	6.10
	pH KCl	5.50

m² with a density of 0.20 × 0.20 m. Phosphorus (30 kg P_2O_5 ha^{-1}) and potassium (35 kg K_2O ha^{-1}) have been applied during rice transplantation. Nitrogen (kg ha^{-1}) is applied at active tillering stage and at panicle initiation according timing in Table 2. Three types of mineral fertilizer have been used for the experimentation: the urea (46-0-0), the super phosphate triple (TSP, 0-45-0) and the potassium chloride (KCl, 0-0-60).

Chemical analysis

Five top-soils (0-0.20 m) samples have been collected in each plot before soil tillage. Samples have been dried on air and sieved at 2 mm. Soil analysis included pH H_20 (1:2.5 extract), electrical conductivity of the 1:5 soil-extract (Exchangeable Cations), total carbon, total nitrogen, phosphorus-Bray1, and exchangeable bases (extraction with ammonium chloride) according to Van Reeuwijk (1992) method.

Plant samples have been collected according to Witt et al. (1999) method. Paddy yield was estimated on 6 m² (3 m × 2 m) for each plot and grain moisture was determined using "Riceter grain moisture meter, Kett Electric Laboratory, Tokyo, Japan" device and paddy yield corrected to 14% moisture content. The nitrogen concentrations of grains were determined using 12 plants at physiological maturity. Samples were then dried in oven at 70°C until constant moisture of 3%.

Statistical analysis

Statistical analyses of data were conducted using Genstat 5 Release 4.1 (Payne, 1997). Paddy yield and nitrogen uptake data

Table 3. Effect of fertilizers and varieties on paddy yield in 2005 and 2006 wet seasons.

Treatment		Paddy rice yield (kg/ha)	
		2005	2006
Fertilizers	0 N (kg/ha)	1900[a]	2012[a]
	40 N (kg/ha)	2413[b]	2817[a]
	80 N (kg/ha)	3105[c]	4654[b]
	120 N (kg/ha)	6106[d]	4904[b]
	160 N (kg/ha)	7062[e]	7650[c]
	F Probability	<.001	<.001
Varieties	4418	3490[a]	4244[a]
	NERICA L 41	4473[b]	4747[c]
	NERICA L 60	3388[a]	4104[a]
	NERICA L 20	4462[b]	4489[ab]
	NERICA L 19	4475[b]	4453[ab]
	F Probability	<.001	0.011
Fertilizers*Variety Interactions		Probability= 0.113	Probability=0.601

Average yields followed by the same letter in each column do not differ significantly by student Newman Keuls test at 5% level of significance.

were submitted to a two way analysis of variance (ANOVA) with confidence interval of 95%.

RESULTS

Effect of fertilizers on paddy yield

The results show a non-significant interaction between varieties and fertilizers respectively for 2005 (P=0.113) and 2006 (P=0.601) (Table 3). This result allows the comparison of each treatment per factor (fertilizers and varieties).

Analysis of variance showed significant differences between the yield of different nitrogen fertilizers (all varieties taking into account). For the 2005 wet season, five homogeneous groups are differentiated (P<0.001). Plots fertilized with 160 kg N ha^{-1} get the best yield followed by plots fertilized with 120 kg N ha^{-1}. They got more than 3 to 5 t of paddy ha^{-1} compared to the plots fertilized with 80, 40 and 0 kg N ha^{-1}. At the 2006 wet season, three homogeneous groups are differentiated (Table 3). Plots fertilized with 160 kg N ha^{-1} got the best yield. This yield is significantly different with those of plots fertilized with 120 and 80 kg N ha^{-1}. The lower yields are obtained with 0 and 40 kg N ha^{-1}.

Like fertilizers, results show significant differences between varieties (all fertilizers taking into account) at 2005 (P<0.001) then at 2006 (P<0.001) wet seasons. For the 2005 wet season, two homogeneous groups are differentiated; the best varieties were NERICA L 41, NERICA L 20 and NERICA L 19. This group differs significantly with the group of 4418 and NERICA L 60 varieties. For the 2006 wet season, results show two heterogeneous groups; NERICA L 41 has got the best paddy yield. It differs significantly from 4418 and NERICA L 60 varieties. But it forms with NERICA L 20 and NERICA L 19, a heterogeneous group.

Relationship between varieties to N supply and absorption

The results showed a significant interaction between varieties and fertilizers respectively for 2005 (P<0.001) and 2006 (P<0.001) wet seasons (Figure 1). This result allowed the comparison of the combination of factors (fertilizers and varieties).

For the 2005 wet season, the highest levels of nitrogen uptake are obtained with NERICA L 41, NERICA L 20 and NERICA L 19 fertilized with 120 or 160 kg N ha^{-1} (Figure 1). Lower levels of nitrogen uptake are obtained with the combination of all varieties with low doses of nitrogen supply and with the combination of 4418 and NERICA L 60 varieties with the same amounts of nitrogen supply having good results with other varieties. With 0N plots, it was still the NERICA L 41, NERICA L 20 and NERICA L 19 varieties which showed a good absorption of soil nitrogen.

Like the 2005 wet season, the same trends are observed in 2006 with best nitrogen uptake for the combinations of NERICA L 41, NERICA L 20 and NERICA L 19 varieties (Figure 2). However, the level of absorption was higher than 2005. The soil nitrogen has been more profitable for these three varieties compared to 4418 and NERICA L60 varieties with lower levels of

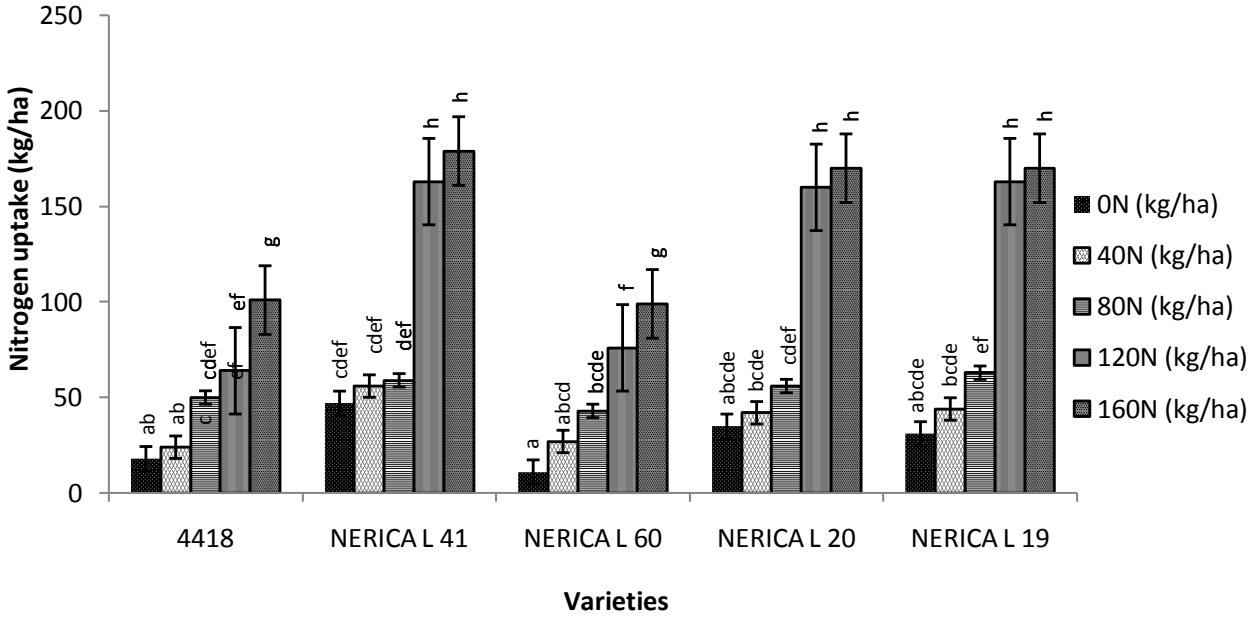

Figure 1. Effect of fertilizers*variety interaction on nitrogen uptake in 2005 wet season. Average nitrogen uptakes followed by the same letter in the graph do not differ significantly by student Newman Keuls test at 5% level of significance.

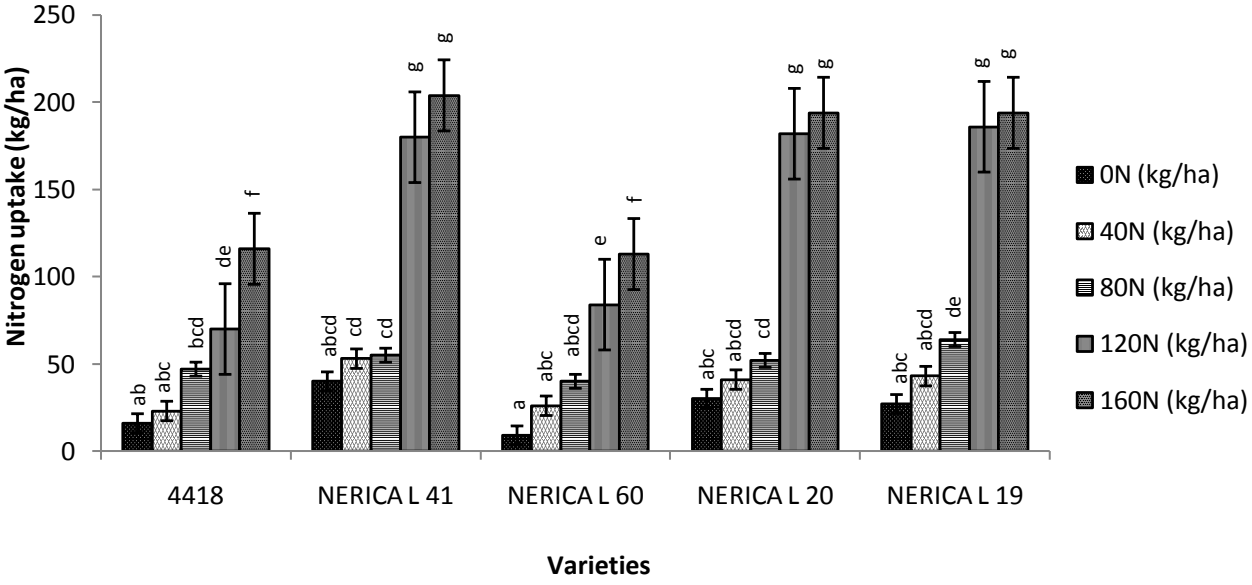

Figure 2. Effect of fertilizers*variety interaction on nitrogen uptake in 2006 wet season. Average nitrogen uptakes followed by the same letter in the graph do not differ significantly by student Newman Keuls test at 5% level of significance.

nitrogen absorbed. For all varieties tested, N accumulation increased significantly with the availability of nitrogen. Analysis of N uptake showed that almost 97% of paddy yield variations are explained by N uptake at maturity (data not shown) for both seasons. For some varieties, most nitrogen was available, best are their response to N absorption. Maximum uptake is situated at about 100 kg N ha^{-1} for two varieties (4418 and NERICA L 60) while it is up to 170 kg N ha^{-1} for the three other NERICAs (L 20, L 19 and L 41).

The paddy yield evolved following genotypic behaviour of varieties to nitrogen uptake and use efficiency. Maximum N uptake for 4418 and NERICA L 60 varieties were 99 and 102 kg N ha^{-1}. However, highest uptake rates are observed with others NERICAs for nitrogen use

like NERICA L 20, NERICA L 19 and NERICA L 41. For high rates of N uptake, high yields are observed for all varieties. For NERICA L 41, NERICA L 19 and NERICA L 20 varieties, lower N uptake rates corresponded to high yields.

DISCUSSION

Effect of fertilizers on paddy yield

The results of our study confirm those obtained by many others authors. Based on the response of rice according to nitrogen supply, the rice genotypes have been classified in " efficient"," not-efficient" and " inferior type" (Gerloff, 1976; Gourley et al., 1993; Shukla et al., 1998). The genotypes which do not respond to the increasing doses of N supply because of their weak potential of adaptation to high doses or their weak productive potentials are identified as "inferior type"; the yield of these varieties are influenced by other factors than N availability; two of our varieties (4418 and NERICA L 60) could be identified as inferior type according to these criteria. Those which respond to lower N-Soil and N-fertilizers as well as to high level are identified as “efficient" varieties (Singh et al., 1998). Three of our varieties could be identified as efficient according to these criteria (NERICA L 41, NERICA L 19 and NERICA L 20). These varieties are more efficient for yield building. The varieties which respond to lower N supply but not to increased level are “not efficient”. In our case, none of varieties respond to this criterion.

Relationship between varieties to N supply and absorption

A study carried out during three successive years at the IRRI in Philippines (Singh et al., 1993) showed that when nitrogen does not constitute a constraint, the available nitrogen is the first factor limiting the paddy yield. The solar radiation accounts for less 5% in the observed yield gap without nitrogen. Without looking if available N comes from soil or fertilizer, the genotypic variation remains consistent. The yield gap without nitrogen supply is due to the genotypic variations in the capacity of the different varieties to absorb and to use the nitrogen.

The most efficient varieties are researched by the most part of rice breeders in Africa. Given the weak use of fertilizers by farmers (Nébié, 1995; N’Diaye et al., 1997; Wopereis et al., 1999; Haefele et al., 2002; Segda et al., 2004) such varieties appear to be most suitable. Besides, as these same varieties respond to variable levels of nitrogen, this criterion could interest those of the farmers who afford to use high levels of fertilizers. Three lowland NERICA genotypes (NERICA L 41, NERICA L 19 and NERICA L 20) were identified for high yield in both non-fertilized and fertilized conditions. This result indicates that interspecific breeding between *O. sativa* and *O. glaberrima* appears to offer an effective approach to increasing lowland rice productivity. This finding is consistent with Heuer et al. (2003), Oikeh et al. (2008), Rodenburg et al. (2009), and Saito et al. (2010a). Similar results were also reported from previous studies in flooded lowlands rice in Asia, Latin America and West Africa (Kawano, 1990; Peng et al., 2000; Saito et al., 2010b). During the last decades, many investigations have been reported, related to nitrogen efficiency of different plant genotypes (Fang and Wu, 2001; Fang et al., 2004, Zhao et al., 2012). Matsunami et al. (2013) indicated that substantial genotypic variation in N uptake ability under water deficient conditions exists among diverse rice genetic resources. Other field experiments have shown that genetic variability for N use efficiency exists in rice (Tirol-Padre et al., 1996; Singh et al., 1998; Inthapanya et al., 2000b). Therefore, plant breeders need to develop cultivars that can exploit N more efficiently, in order to minimize loss of N from the soil and make more economic use of the absorbed N, which could increase rice yield and improve environments. The main goals for rice production systems are to get more grain yield, to reduce the production cost and to minimize the pollution risk for the environment (Zhao et al., 2012).

Conclusions

The paddy yield increases significantly according to the quantity of nitrogen fertilizer applied. It evolves according to the genotypic behavior of the varieties in the absorption and the efficiency of nitrogen use. Three NERICA varieties (NERICA L 19, NERICA L 20 and especially NERICA L 41) can be considered as "efficient varieties" according to the use of nitrogen.

The NERICA varieties can create a major impact in improving incomes and food security of farmers. This may be the way to a real "green revolution" in Africa. However, it would be necessary to carry out complementary activities: (i) To assess the economic profitability of each input option, and (ii) To extend the study to all NERICA varieties diffused.

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Assessing the role of climate-smart agriculture in combating climate change, desertification and improving rural livelihood in Northern Nigeria

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Worldwide emphasis has been placed on designing approaches with regard to the needs of sustainable development. Climate-Smart Agriculture (CSA) is one key agricultural development approach aimed at sustainably increasing productivity and resilience, while also reducing/removing emissions of greenhouse gases. Although many countries will be expected to adopt this approach, its applicability in an African context is not very clear, well studied nor has its sustainability been assessed. We used the Sustainability Assessment of Energy Technologies Framework to assess the applicability of CSA in combating climate change, desertification and improving rural livelihood in an African context. We also assessed the opportunities and constraints to the adoption of this approach in Northern Nigeria. Data was collected using key informant interviews and field observation to assess the current status of agriculture in Northern Nigeria. The results showed that CSA is strong in aspects such as participation and sustainable use of resources but weak in aspects of compensation and equal distribution of benefits and costs. Many small-holder farmers have inadvertently practiced CSA as part of the traditional farming system. While the existence of CSA in current practice is a major element in its favour, the lack of a coherent climate mitigation approach and poor institutional structures are both detrimental. Sustainable agriculture will require a wider societal change towards appreciating the balance between agriculture and environmental change. We suggest four main areas in need of urgent change: political commitment, human and financial investment, incentives and information.

Key words: Climate-smart agriculture, sustainability assessment of energy technologies, desertification, rural livelihoods, northern Nigeria.

INTRODUCTION

Agriculture has been high on the political agenda as it is increasingly recognized as one of the biggest drivers of environmental change (Smith et al., 2007; Liverman and Kapadia, 2010; Foresight, 2011). Agricultural lands occupy about 40 to 50% of the Earth's land surface (Smith et al., 2007). It is estimated that agriculture is responsible for about three-quarters of tropical deforestation (Carr, 2004; Skutsch et al., 2007; Wollenberg et al., 2012) and accounts for about 10 to 12% of the total global anthropogenic emissions of

greenhouse gases (GHGs) in 2005 (Smith et al., 2007). Yet, the world needs more food than ever before to sustain the increasing population of people living in extreme hunger, especially in Africa where about 70% of the people are engaged in some sort of agricultural activity (African Union (AU, 2012). While there is need to redouble efforts in agriculture in order to fight hunger, there is adequate evidence for us to be wary of its environmental sustainability.

The need for a more sustainable approach to agriculture has led to suggestions that agriculture is the key and holds enormous potential to contribute to any strategy to adapt to climate change and reduce emissions particularly in an African context (Garrity et al., 2010; Beddington et al., 2011). To this end, over the last decade, there has been development and promotion of several initiatives aimed at promoting sustainable agriculture (Lichtfouse et al., 2009; Beddington et al., 2012). Many of these have emphasized the need for African farmers to engage in an agricultural system that ensures food security whilst at the same time addressing and adapting to climate change. Also emphasized is the need for policy makers to recognize the nexus between agriculture and environment change, which needs to be balanced and taken into account on decision making for agriculture.

Climate-smart agriculture (CSA) is one approach that has been championed as the “holy grail” of agricultural development (Naess, 2011) ensuring that agriculture is key to climate change adaptation and mitigation (Wollenberg et al., 2011; Beddington et al., 2012). Climate-smart agriculture is derived from the acronym SMART, where S stands for specific, M stands for measureable, A for achievable, R for reliable and T for timely (McCarthy et al., 2012). According to the Food and Agriculture Organization (FAO) (2010), CSA is a method of agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes greenhouse gases (mitigation) while enhancing the achievement of national food security and development goals. There are three main pillars to any CSA approach: the sustainable increase in agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gases emissions. As such, agriculture is considered to be “climate-smart” when it achieves these three objectives. This concept is therefore a good way to unite the agendas of agriculture, development and climate change under one brand (Neufeldt et al., 2013).

The CSA approach has been widely championed with a rapid uptake of the concept by the international environments and cultures to ensure such community, national entities and local institutions. There is need, however, to assess its applicability in diverse recommendations are more than panaceas (Ostrom et al., 2007). It is not uncommon for similar initiatives to be introduced as a “panacea” encouraging many developing countries to invest scarce resources only to realize the approach is rather not suitable for their society. Having said that, CSA has been applied with positive outcomes in some African societies, namely Yatenga, Burkina Faso; northern Cameroon; and the Nile Delta, Egypt (Food and Agriculture Organization, 2010; Branca et al., 2011). There is even the suggestion that the adoption of CSA practices in northern Nigeria will improve indigenous/traditional agricultural systems as well as encourage the practice of agro-ecological agricultural systems (International Assessment of Agricultural Knowledge, Science, and Technology for Development (IAASTD, 2009). This, however, has not been empirically proven and there are few studies supporting this assertion. Establishing the potential applicability of climate-smart agriculture in the context of developing societies is critical to creating its wide uptake by farmers and enhances the political will required to motivate deep transformations within the policy sector. Yet, there have been no studies assessing the potential of this approach in Nigeria, which is the most populous country in Sub-Saharan Africa.To this end, we ask two fundamental questions: first, to what extent can CSA be said to be sustainable based on sustainability assessment measures? It is important for this to be appraised in terms of its potential influence on the environment, its implications for sustainable development and the potential cultural and socio-economic consequences. Our second question is site specific as we seek to understand what are the enabling political, social and economic conditions needed for the adoption of climate-smart agriculture in Northern Nigeria.

This is a major challenge in itself, considering that great policies have often been undermined by cultural and political factors. Thus, the focus of this paper is to explore the state of agricultural climate change mitigation in Northern Nigeria, with a focus on identifying the feasibility, opportunities and challenges for adopting climate-smart agriculture in the region. Knowledge generated from this assessment will be useful in location-specific information for building knowledge and capacities in climate-smart interventions in similar societies. Lessons learnt will also aid the future adoption of climate-smart agriculture in the region and serve as practical guidance for the implementation of agricultural emissions reduction initiatives, based on experience and best practices. The ultimate purpose is to accelerate efforts

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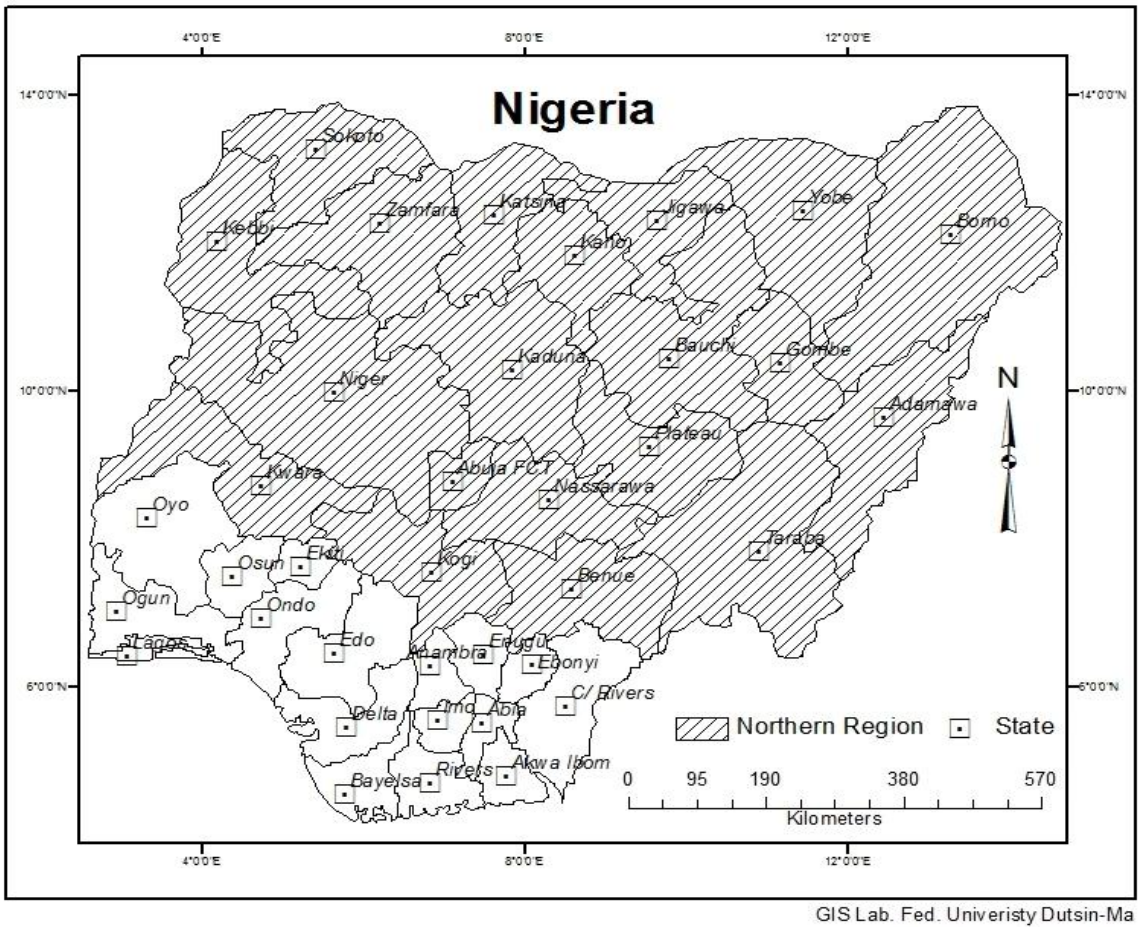

Figure 1. Map of Nigeria showing Northern Region.

towards mitigating agriculture-based climate change while at the same time enhancing livelihoods and food security.

METHODS

Study area

It is estimated that about 70% of the land area in Nigeria geographically belongs to the Northern region of the country (Oladipo, 1993). The region which lies between latitudes 06° 27^{l} N to 14° 00^{l} N and between longitudes 02° 44^{l} E and 14° 42^{l} E is predominantly agrarian, engaging especially in grain farming and cattle rearing. This provides the means of livelihood for the majority of the people. The people of the region, however, are generally regarded to be poorer both in financial and educational terms, than other parts of the country (Omonona, 2009). There are three major climatic belts in northern Nigeria: Guinea Savannah, Sudan Savannah and Sahel Savannah. Rainfall and temperatures vary significantly across the three climatic and ecological zones. Generally speaking, the mean monthly maximum temperature varies between 28 and 40°C. In the semi-arid zones comprising the Sudan and Sahel, the maximum temperatures could be as high as 40°C between March and May while at the lower end the maximum temperatures of 28°C are experienced between December and January (Akor, 2012). According to the Nigerian Meteorology Agency (NIMET)(2008), the northern region has been experiencing lower than normal rainfall but progressively became wetter thannormal in the year 2010 (Figure 1). The annual rainfall in the region ranges from 300 to 1000 mm. There is further evidence suggesting that climate is fast changing. A comparison of the mean temperatures of previous years from 1941 to 2000 was carried out and revealed evidence of long-term temperature increase across the country, especially in the North Nigerian Meteorology Agency (NIMET, 2008). The most significant increases recorded were in the North with average temperatures rising by 1.4 to 1.9°C. Similarly, a comparison of rainfall records from 1971 to 2000, using the combination of the late onset and early cessation of rainfall revealed that the length of the rainy season had shortened in most parts of the country (Building Nigeria's Response to Climate Change (BNRCC), 2011). Also, the study found that between 1941 and 2000, the annual rainfall in most parts of Nigeria has decreased by 2 to 8 mm. Seasonal rainfall and drought are recurring and have become a permanent feature of Northern Nigeria. The dry season, which lasts almost ten months, is very pronounced with rainfall occurring only seasonally but is often intensive, making it necessary for farmers to employ soil moisture conservation techniques.

This paper is based on a case study conducted in the Dutsin-Ma Local Government Area (LGA) in Katsina State, Northern Nigeria. The majority of the inhabitants there are poor, living below the US$1 per person per day threshold. The Local Government Area has a population of 169,829 in about 18,800 households with an

average household income of N18, 989 (US$122). The dominant occupation for people is farming, engaging in the cultivation of crops such as millet, sorghum, cowpea, beans and maize.

Agricultural practice and environmental change in Northern Nigeria

The most common agricultural system in Northern Nigeria has been traditional bush fallowing (Adams and Mortimore, 1997), in which the farmer cultivates a plot, usually for one to three years, and then abandons it temporarily (for a period of three to ten years) to allow the plot to regain soil fertility. Rapid population growth and land shortage, however, have drastically reduced the amount of arable land available to farmers, reducing fallow periods considerably and in most cases, continuous cultivation has emerged. Farmers have thus continually engaged in slash-and-burn by cutting down the vegetation on plots and then setting fire to the remaining foliage, using the ashes to provide nutrients to the soil for planting food crops. This system of agriculture is a main source of deforestation and a major cause of draught, desertification and climate change in northern Nigeria (Farauta et al., 2011). This situation is further aggravated by the overgrazing of lands by nomads moving southward from the ravaging draught in the Sahara Desert. The rate of desert encroachment in the region is put at 0.6 km per annum while the rate of deforestation is about 350,000 ha p/a (Federal Ministry of Environment (FME), 2000). There is little doubt that agriculture as practiced currently in the region contributes to climatic change (Chianu, 2004).

Successive Nigerian governments have attempted to mitigate the impacts of climate change and desertification in the region by formulating and implementing policies. Recent policies include: the National Erosion and Flood Control Policy; the National Environmental Sanitation Policy; the National Forestry Policy; the National Drought and Desertification Policy and the National Policy on E-Waste Control and Management (Medugu, 2012). These policies, however, have failed to yield the required results. There are a number of reasons adduced to explain the failure of past policies. Firstly, the policies only focused on mitigating the immediate impact of desertification without addressing it holistically, including the causes of desertification, which comprise over-exploitation of natural resources, especially natural vegetation and water sources for domestic and commercial purposes (Oladipo, 1993; Audu, 2013), and unsustainable agricultural practices which result in decreased crop productivity and emission of greenhouse gases in the atmosphere (Farauta et al., 2011; Ifeanyi-Obi et al., 2012). Secondly, there was a lack of provision for long-term measures and opportunities for the people and in particular the most vulnerable groups, such as women and children, in the region to cope with the impacts of climate change and desertification (Andrade et al., 2011; Falaki et al., 2012). Lastly, there was a lack of incorporation of indigenous livelihood practices and initiatives in agricultural policies, especially those aimed at combating climate change and desertification phenomena in the region (Enete and Amusa, 2010). Therefore, any agricultural development policy to address the problem of desertification cum climate change in northern Nigeria will require a comprehensive approach that incorporates the abilities to increase agricultural productivity and incomes sustainably now and in the future; adapts and builds resilience to climate change and reduces or removes greenhouse gases emissions using local knowledge and initiatives. These are some of the pillars of climate-smart agriculture.

Conceptual framework and research methods

Stakeholders, especially policy makers, have to make decisions about the technologies/initiatives that are adopted to ensure that agricultural practices are sustainable. In order to make the best decision with regard to the needs of sustainable development, sustainability assessments are necessary. There are a number of assessment methodologies, such as the Sustainability Assessment of Technologies (United Nations Environmental Programme (UNEP), 2012) and the Social Assessment of Conservation Initiatives (Schreckenberg et al., 2010); however, this study will adopt the Sustainability Assessment of Energy Technologies (SAET) framework (Grunwald and Rosch, 2011) because of its emphasis not only on ecological aspects but also on issues important in an African context, such as questions of conservation of cultural functions, participation, autonomous self-support and equal opportunities, including aspects of human health. The SAET framework aims to integrate social and environmental factors into sustainability considerations which are currently dominated by economic concerns. This framework also recognizes the weakness of previous assessment methodologies, which have depended on assumptions about the future, and assessment criteria based on the available data (Scrase and MacKerron, 2009) without resource to societies where there is paucity of data. One of the strengths of the framework is its ability to reduce arbitrariness in the assessment process using the concept of integrative sustainability. The initial focus of application is on energy management related issues. We do find, however, that this framework is applicable in this case because of its holistic nature and emphasis on rules important for sustainability in an African context.

The framework is based on three general goals of sustainable development, being the condition precedent to sustainability. These are: securing human existence; maintaining society's productive potential (comprising natural, man-made, human and knowledge capital); and preserving society's options for development and action. Each of these are further broken down into rules which need to be fulfilled for each goal to be achieved.

Data collection

The assessment of CSA was made by analysing secondary source data. As the concept of CSA is relatively new, there is little relevant research conducted so far; hence, we are limited on the number of published literature we can rely on. This means that most of our analysis is based on the CSA source book (Food and Agriculture Organization, 2013). An effort was made to include other sources such as peer-reviewed materials presented in journals, books and national and international conference presentations. These sources were collected through an extensive literature review using academic reference databases including Web of Knowledge, Science Direct and Cambridge Scientific Abstracts (including databases such as Aqualine, Aquatic Sciences and Fisheries Abstracts, Biological Sciences, Conference Papers Index for life, environment and aquatic sciences, GeoRef, International Bibliography of the Social Sciences, Oceanic Abstracts and Sociological Abstracts). Internet-based search engines (e.g. Google scholar, scirus.com) were also used to identify relevant 'grey literature'. A structured search using Boolean logic was conducted using a wide range of terms related to the CSA. Sources were investigated and information collated, with particular reference to the principle of sustainability.

Primary data was collected using unstructured interviews, which contained questions that could be changed or adapted to match the respondent's intelligence, understanding or beliefs. Unlike structured interviews, they do not offer a limited, pre-set range of answers for a respondent to choose from but instead rely on listening to how each individual responds to the questions. Interviews were conducted with respondents drawn mainly from two categories: government officials – policy makers including agricultural extension workers at both state and local government

level, and local community respondents which included small-holder farmers and key informants, such as chiefs and elderly people within the communities. Interviews with government officials were conducted in English The majority of local community respondents, however, could not communicate in English or even Pidgin English; hence, interviews were conducted in the local dialect of Hausa. Respondents were questioned to obtain information on the status of CSA knowledge in the region. In total, fifteen respondents were interviewed directly (face-to-face) between August 2013 and November 2013 using a structured questionnaire. The sample was made up of ten local community stakeholders and five government officials. The questionnaire was structured into three sections: the first section captured the demographic and socio-economic characteristics of respondents; the second dealt with general information about current farming practices; and the third asked questions regarding their challenges and expectations. These interviews were complemented by direct field observation.

RESULTS AND DISCUSSION

Sustainability assessment of climate-smart agriculture (CSA)

In the following presentation, we provide neither a detailed nor an overarching assessment but instead the descriptive assessment of the sustainability of CSA in an African context that has been lacking in the literature. Our review, specific to the Sustainability Assessment of Energy Technologies Framework, was judged from the literature (mainly the CSA sourcebook) and personal knowledge and observations from the field. Although it was not practical to test the veracity of information presented in the available sources systematically, we did seek to ensure that, wherever possible, results were based on data presented across multiple sources.

Securing mankind's existence

The first goal is securing mankind's existence, under which there are five major rules to be fulfilled in order to achieve sustainability. These are: protection of human health; securing the satisfaction of basic needs; autonomous self-support; just distribution of opportunities for using natural resources; and compensation of extreme differences in income and wealth (Table 1).

CSA emphasis the need to ensure the protection from dangers and intolerable risks for human health due to anthropogenic environmental impacts. This rule, however, needs specific emphasis in order to underscore its importance. Currently, it is mentioned alongside ecosystem health in which case its emphasis could be diminished. This rule is important in Nigeria because of the growing concern for heavy metal contamination of agricultural lands under long-term application of inorganic fertilizers and organic wastes, which also has serious deleterious effects on human health (Agbenin, 2002). Achieving this rule will no doubt help reduce risks and deaths from agricultural land contaminations. The second goal has to do with the ability of CSA to contribute in securing the satisfaction of basic needs for the people.

The emphasis of CSA is on the provision of food, with little mention of other basic needs, such as shelter and clothing. While it is true that 'food is not only a basic need', it is pivotal for maintaining livelihood. It is important, nonetheless to emphasise the significance of other basic needs, such as shelter and clothing, in any sustainable initiative. In many African cultures external appearance matters as much as the internal. Many people believe that the inner peace will be disturbed when the external appearance is weak. In addition, adequate clothing and shelter will help protect against health challenges, such as farmers contacting water-borne diseases because they lack shoes. Achieving autonomous self-support is the third rule. CSA supports and emphasizes education to raise environmental awareness especially with the farmers. The biggest emphasis has been on sending children to school. There is no emphasis on education for the farmers and their household in order to enhance their future potential. It is important to emphasise preparation for ageing populations, as many agrarian African societies are losing young ones to the towns. This has left many elderly farmers without support in their old age.

The need to ensure a just distribution of opportunities for using natural resources is another rule for sustainability. CSA emphasises the need to ensure the fair and equitable sharing of benefits (and cost) arising from the use of genetic resources. What has been left out is emphasis on the need of any such initiative to ensure that people's access to the necessary resources is assured. Currently, this rule is often being fulfilled through the traditional ownership structure. When this, however, is usurped by the formal state institutions, poor farmers can be displaced and denied access to their farm lands under the Land Use Act of 1978, which nationalised all land and vested its management to the state. The law provides that occupancy can be revoked if the land is required for other activities (Constitutional Rights Projects (CRP), 1999). This is often done without compensation. The final rule, which is also linked to the previous, is to ensure compensation of extreme differences in income and wealth. This is to guarantee that farmers who experience temporary loss of profits are not left on their own but are adequately compensated to reduce disparity among farmers. There is little or no mention of this rule in CSA; however, the approach did emphasise payments for environmental services (PES), a mechanism for compensating farmers and farming communities for maintaining ecosystem services.

Upholding society's productive potential

The second goal is made up of five rules (Table 1). The need to ensure sustainable use of renewable and non-renewable resources through the use of diverse energy

Table 1. Sustainability Assessment in Northern Nigeria.

Goals	Rules	Weight as a sustainable strategy	Remarks	Implications in the African context
Securing mankind's existence	Protection of human health	xxx	Emphasised alongside ecosystem health	Can help reduce risk from misapplication of fertilisers
	Securing the satisfaction of basic needs	xx	Emphasis on food with little mention of shelter and clothing	Ensures food security and reduces risk of sickness from inadequate clothing and shelter
	Autonomous self-support	x	Little emphasis on preparation for old age in the face of rapid flow of youths in urban areas	Prepares support for farmers in their old age
	Just distribution of opportunities for using natural resources	xx	Emphasis on benefit and cost sharing, but less on access to resources	There are changes needed to formal laws in order to reduce usurpation of farmlands for other uses
	Compensation of extreme differences in income and wealth	x	Emphasis on payment for ecosystem services and little or no mention of compensation for income differentials	Reduces exploitation among farmers
Upholding society's productive potential	Sustainable use of renewable resources	xxx	Emphasises efficiency of available energy, as well as increasing the proportion of renewable energy	Can help create a good balance between increasing emphasis on fertilisers and organic manure through mixed farming
	Sustainable use of non-renewable resources	xx	Advocates reducing reliance on non-renewable external inputs	Attempts to stem the tide of possible move from renewable to non-renewable resources
	Sustainable use of the environment as a sink	xxx	Emphasises role of aquatic ecosystem, forests and tree planting as environmental sinks	Can aid conservation of wetlands, which are often cleared in many African societies. Also serves as a good platform to encourage tree planting
	Avoidance of unacceptable technical risks	xx	Emphasis centres on concerns with long-term potential impacts of biotechnology	With the rapid uptake of biotechnology, directs emphasis to negative impacts
	Sustainable development of real, human and knowledge capital	xxx	Emphasises promotion of integrated systems that incorporate scientific and local knowledge sources	Aids promotion of indigenous knowledge
Keeping options for development and action open	Equal access to education, information and occupation	xxx	Emphasises social protection including access to social services for education, health, nutrition	Helps enhance societal organisation through reduction in disparity between rich and poor in society
	Participation in societal decision-making processes	xxx	Emphasises the need to broaden stakeholder participation with due consideration to cross-sectorial negotiations and planning processes	Ensures local people have a say in their development

Table 1 contd.

	Conservation of nature's cultural functions	x	Less emphasis placed on cultural factors	May lead to a situation where culture is seen as entirely 'good' or completely 'bad'
	Conservation of 'social resources'	x	Emphasises the interactions between sectors.	Need to encourage inter-personal interactions especially among farmers.

sources is one of the rules mostly emphasised by CSA. The approach recognises the role of renewable and non-renewable energy through integrated food and renewable energy production. It is emphasised in the CSA source book that in promoting energy-smart food, a balance needs to be maintained between improving access to energy sources and increasing the efficiency of available energy, as well as increasing the proportion of renewable energy. This balance must be based on local conditions and the economic trade-offs between different options. CSA also emphasises a crop production that looks at reducing reliance on non-renewable external inputs, and capitalizing on/enhancing natural biological processes to improve production in a more environmentally friendly way, avoiding the degradation of production's relevant natural resources. Currently, many societies in Africa practice mixed farming in which case animal manure is used to complement soil nutrients. However, there is a gradual decline in this practice leading to the use of non-renewable resources gaining more ground. CSA also emphasises the sustainable use of the environment (especially aquatic ecosystems and forests), as an important sink for carbon and nitrogen fluxes on the planet. There is also emphasis on the role that tree planting can play in mitigating climate change through carbon sequestration. Apart from concerns with the long-term potential impacts of biotechnology, CSA does not really envisage many potential technical risks that may be associated with the adoption of this approach, as other such technical risks are given very minimal focus. One main technical initiative of CSA is encouraging biotechnology. It rightly emphasises the need for a sound and integrated approach to bioenergy, particularly biofuel development, that is required to reduce the risks and harness the opportunities related to bioenergy development. This emphasis is also appropriate for developing societies where there is a growing uptake of biotechnology in the agricultural sector and can act as a guide against any potential negative impacts. The final rule under this goal is to ensure sustained real, human and knowledge capital, which CSA recognises through its emphasis on building and mobilising knowledge capital as essential for sustainable development. The approach also emphasises the importance of indigenous knowledge, which is often ignored in many western developed concepts and has become an important factor in sustainable development.

Keeping options for development and action open

Finally, the third set of rules aims to achieve the goal of keeping options for development and action open. The rules include equall access to education, information and occupation, participation in societal decision-making processes, and conservation of nature's cultural functions, 'social resources' and cultural heritage and diversity. Aside from the emphasis on the need to ensure access to natural resources, CSA strongly advocates for access to information (especially information on CSA) to be made available to all stakeholders especially the poorest and the most insecure in society. Besides access to information, CSA proposes three main types of social protection: labour market policies; social insurance, such as health insurance; and social services (e.g. access to social services for education, health, nutrition). This is an important rule, which will enhance societal organisation through a reduction in the disparity between rich and poor. Participation in societal decision-making processes is another of the strongest points of CSA.

The approach emphasises the need to broaden stakeholder participation with due consideration to gender in cross-sectoral negotiations and planning processes. It also underlines that participation should go beyond presence and should include information sharing which will warrant that all sides, including locals, are aware and have access to equal levels of information. In most African societies, however, ownership of resources and societal hierarchies are a crucial precondition for being able to participate in societal processes. One weakness of CSA is its almost near absence of emphasis placed on cultural factors, which are often more important than physical, and even economic and social, characteristics in determining sustainability in an

African context where people hold diverse cultural values. Lack of emphasis can lead to situations where culture is seen as entirely 'good' or completely 'bad'. In other words, in dealing with cultural factors people may blindly accept everything or dismiss cultural values as totally harmful. The final rule is to ensure the conservation of social resources. Social resources in this case refer to the means through which interactions take place. CSA emphasises the interactions between sectors and the needs of the different involved stakeholders in order to maintain close communication. In an African context where the informal is often more important than the formal, it is essential to place emphasis on interpersonal relationship especially among farmers.

It is important to highlight the fact that there is cross-cutting of goals between rules on different levels. For instance, access to goods and services is seen as a prerequisite for all members of society in order to have the same opportunities to realise their own talents and plans for life.

Awareness of climate-smart agricultural knowledge in Northern Nigeria

The study examined awareness of the CSA approach among government officials including extension workers and field researchers, and local communities including farmers and chiefs. We interviewed both groups of respondents as we wanted to find out more about people's awareness and knowledge, which are crucial factors in the success of the CSA. The research found that none of the respondents were aware of the term 'climate-smart agriculture' and that younger farmers in the 20 to 35 age group were most interested in knowing more about this approach, while the older farmers appeared to be uninterested. One of the younger respondents stated that:

"I am hearing about this (CSA) for the first time. What is it all about?"

After briefly explaining the concept to him, he went further to say:
"If it is a new technique that will help us, we need to know so that we can also tell our (other) farmers about it and how they can go about practicing it."

This lack of awareness is not restricted to local people but also to government officials interviewed from the Ministry of Agriculture, the Ministry of the Environment and various research/academic institutions. It is noteworthy that these are the people charged with the responsibility for educating farmers about appropriate agricultural practices in the region. During the interview session, the representative of the agricultural extension workers said:
"I am aware of the need for sustainable agriculture. I was not aware of this new process (CSA) […] I do communicate with federal ministry in Abuja and many NGOs […] When we communicated with them, they never mentioned this to us."

Once the concept is explained, most of the respondents tend to equate CSA with traditional practices such as incorporation of hoodlums and crop residues in soils to boost fertility. According to one respondent:

"This thing (CSA) is just another name for the way we practice our traditional agriculture."

Another respondent equated CSA with the practices his father taught him:

"These are some of the things we have inherited from our forefathers […], to us it is normal and we see nothing new about it."

From such responses, it is clear that there could be a possible misconception of the tenets of CSA; hence, there is a great need to create awareness of the CSA approach in the region. The results also showed that while there is general lack of awareness of CSA among locals and policy makers in the region, the practice is already entrenched in some of the practices. Almost a third of those interviewed are currently practicing elements of CSA and the remaining have done so in the past. All of the respondents aged 50 and over have practiced and are still practicing aspects of CSA. This reflects depth of agricultural knowledge, particularly among the older age groups (above 55). Most of the respondents were aware of some CSA practices that increase yields and subsequently income for farmers. For example, one of the officials in the local department of agriculture said that:

"Seeing the problem of increased dryness which has shortened the duration of soil to retain rain water from 90 days to 30 days […] this is gradually reducing farm output in our Local Government Area (LGA) […] we use animal dung, incorporation of hoodlums in soils during tillage and encourage short fallow systems."

An officer of the local farmers association also said that:

"We have been practicing mixed farming, mono-cropping and mixed cropping systems. I usually rear animal such as cows, sheep and goats alongside crops on the same farmlands. The crops produce food for the flocks and the flocks provide manure for the crops from the animal dung."

The ten farmers interviewed were also asked to rank what factors they felt were the most important in a new

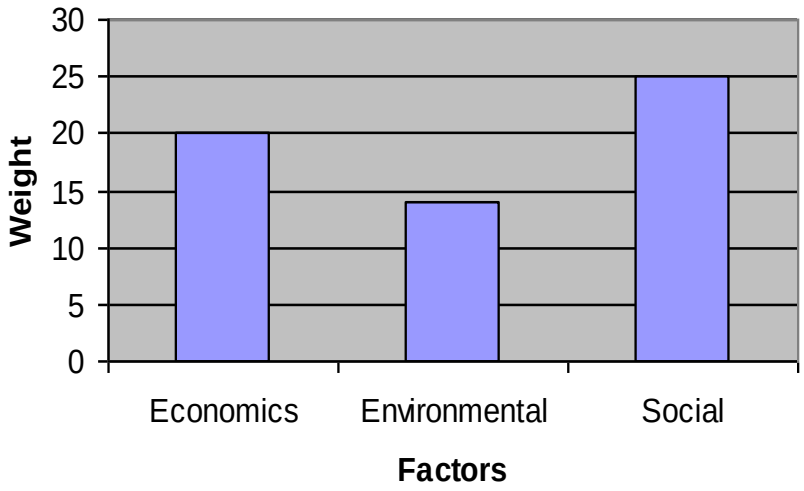

Figure 2. Important factors to consider in a new agricultural approach.

approach. They had to rank economic, environmental and social considerations with three being assigned to the highest rank and one to the least. The results showed that socio-cultural factors ranked highest followed by economic and then environmental factors (Figure 2). Interestingly, despite the strong focus of many on technology, economics and others on the environment, the most important social consideration mentioned was the possibility of them adapting any new initiative with their current practices.

Towards adoption of CSA in Northern Nigeria

We identified four major aspects in which current practices in the region stand to benefit with regards to CSA.

Suitability of climate-smart agriculture practices for Northern Nigeria's agricultural lands

Northern Nigerian agricultural lands are generally characterized by barren landscapes, having little or no vegetation cover. As a result, they are susceptible to high rates of evapotranspiration, rainwater runoff, water and wind erosion, water scarcity, soil nutrients leaching and decreasing soil fertility (Junge et al., 2007). The practice of no-tillage systems, the use of organic manure and agroforestry will improve both the quantity and quality of agricultural lands. This practice has potential to reduce encroachment into marginal lands and the clearing of scarce vegetation. This is because farmers utilise farmlands hitherto considered unprofitable for both crops and animal production due to infertility. Furthermore, CSA practices have the potential to enable small farm holders to achieve agricultural intensification in the region, which can be viewed as the capacity of the farmers to cultivate existing farmlands for a longer period of time without necessarily clearing virgin lands. At the same time they can also be cultivating more farmlands already considered suitable for crops and animal production due to increased yields and income.

Sustainably increasing agricultural productivity and incomes in Northern Nigeria

There is no denying the fact that the general wellbeing of farmers in Northern Nigeria is tied to the productivity of their crops and livestock (Carswell, 1997). Therefore, it was not a surprise that a third of respondents ranked economic considerations highest in the choice of agricultural practice they would embark on. Farmers have found that practices, such as the use of cover crops, crop rotation and intercropping, no-tillage, organic manures, water harvesting and management systems and improved pasture management, are cost-saving. These CSA practices are capable of mitigating the immediate challenges of water scarcity, soil erosion and decreased soil fertility, which often result in inadequate and/or outright lack of quality pasture for livestock, ultimately leading to decreased crops and livestock output, and by extent farmer incomes in Northern Nigeria. These practices are proven to improve agricultural productivity and income levels for rural farm households as well (Food and Agricultural Organisation, 2010; Branca et al., 2011). For example, cover crops have the ability to reduce weeds and grain losses due to pest attacks constantly experienced by farmers in the region. Adoption of water harvesting and management systems will solve the problem of water scarcity experienced by farmers in the region, as well as provide farmers (both crop and livestock farmers) with opportunities to increase their

yields and hence their incomes. Water management techniques such as ridge system, terrace and contour farming, and runoff collection and water storage technologies such as conversion of land mines, ditches and pits to water tanks can be employed in the region to make water available for both crops and livestock uses increasing the yields and income of farmers (Ngigi, 2009. Branca et al., 2011).

Adapting and building resilience to climate change in Northern Nigeria

Adapting and building resilience of rural farm households to climate change and desertification in Northern Nigeria requires the application of on-farm management and technology and diversification practices (Below et al., 2010). Doing the above may not be without constraints. This is because farmers in the region are poor, devoid of basic education and often reliant to cultural and traditional farming techniques that make it difficult for them to adapt easily to modern farming practices (Enete and Amusa, 2010).

On-farm practices are applied to increase the productivity of crops and livestock. The application of on-farm diversification practices in the region is important to provide opportunities for farmers to adapt and build resilience to climate change and desertification. On-farm diversification in Northern Nigeria includes fisheries and aquaculture, bee farming, mushroom farming, orchard and plantation agriculture, urban and peri-urban farming and garden farming (Below et al., 2010; Food and Agricultural Organization, 2010). These practices, if adopted in a widespread manner, have the potential to provide additional food and income to rural farmers in the region and also improve their wellbeing. This is because these often act as a backup to the conventional rain-fed farming system. For example, in a case whereby the rain-fed conventional agricultural system (in which crops and animals in the region depend on the prevailing rainfall conditions in a particular farming season) fails, these modern farming systems which do not depend on rainfall as such but mostly on irrigation and underground water may prove resilient to climate change and desertification and hence provide alternative support to rural farm households to cope with the adverse impacts of climate change and desertification (Below et al., 2010).

Reducing and/or removing greenhouse gases emissions (GHG) in Northern Nigeria

Application of farm management and technologies, such as agroforestry, the use of organic fertilisers (legumes and composting), will go a long way to reduce GHG emission. Practices such as farming with trees on contours, intercropping, multiple cropping, bush and tree fallows, the establishment of shelter belts and riparian zones/buffer strips with woody species, will create an adequate sink for GHG. Agroforestry can contribute to environmental management in the region by protecting the soil from wind and water erosion, acting as a sink for greenhouse gases emissions and protecting the environment from further desert encroachment and climate change. The use of organic fertilizers such as forage legumes/grass mixture and composting can decrease methane emissions while the use of composting manures and crop residues will reduce dependence on synthetic fertilizers which through their production and transportation contribute to GHG emissions (Food and Agriculture Organization, 2010).

Opportunities and challenges towards CSA adoption

A major strength in favour of the adoption of CSA in the northern part of Nigeria includes the fact that many aspects of the approach are already embedded in the current agricultural practices of the region. Most of these already address critical issues such as the farmers' engagement in micro-finance savings, which can help enhance their autonomous self-support or even mixed farming which will ultimately enhance sustainable use of renewable resources and reduce dependence on non-renewable resources. The existence of these long-standing practices should be considered as a first step in a long-term process.

Even though some of these practices exist in the region, they have not been integrated into the broader local and national strategies, policies and planning processes. This lack of an existing link of this approach with any government document translates to no budgetary allocation and, hence, the lack of funding for such initiatives. This is a potential weakness that will need to be addressed in the adoption of CSA. Another weakness towards the adoption of CSA was revealed during the interviews and concerns the little or no knowledge of CSA and the fact that the approach is poorly understood even by extension officers, who would be expected to champion the approach and explain it to the locals. This may be unrelated to another weakness, which is the lack of active non-governmental organisations in the region promoting sustainable agriculture. While there are few organisations promoting tree planting many have failed to address the main cause of desertification, thus treating the symptoms rather than addressing the cause. A further weakness is the limited opportunities for local managers to participate in the international policy that has led to the formulation of this approach.

There are a number of opportunities for the adoption of CSA, chief among these being the willingness of the local farmers and government officials alike to take on this initiative. Moreover, the CSA addresses a number of

social factors, which were found to be paramount for local farmers. One major threat is the possibility of the initiative being left to ministries supporting conservation objectives alone. This might lead to a half-hearted and distorted application of CSA. Non-governmental organisation will need to be encouraged. This might also help to address another threat which is the lack of a permanent budget greatly limiting the ability of CSA to act in the medium- and long-term.

There are four main factors that stand out as important for any adoption of CSA in Northern Nigeria. These are: political commitment, human and financial investment, incentives and information. Political commitment is needed to give CSA the necessary backing and integration into current agricultural and environmental policies in Nigeria. This will also go a long way in addressing the issue of human and financial investment through the provision of budgetary allocation. Part of the financial allocation may have to be channelled into creative incentive mechanisms to encourage farmers who adopt sustainability rules. Finally, there is need to ensure the timely and adequate dissemination of information.

Conclusion

We have argued that introducing noble approaches as though giving orders to a subordinate is not what is needed for sustainable development in Africa. There is need to ensure that the approach is apt and has potential for success. In this line of thought we have argued for the sustainability of Climate-Smart Agriculture for adaptation in Northern Nigeria. Climate-Smart Agriculture has been proposed as an approach that can combat climate change and desertification comprehensively by emphasising adaptation to climate change. Having assessed the approach through the prism of the SAET framework, we found that broadly speaking it fits with what can be termed as a sustainable technology. Admittedly, there are many aspects, such as the emphasis on cultural functions, that will need to be addressed. CSA in societies like Nigeria where the poor are often cheated out of programmes should integrate all the needs of the disadvantaged into the policy before its final adoption. Such a review has become necessary because the approach, as currently conceived, does not do enough justice to some of the critical issues in the agricultural sector in Nigeria. There is need for an all-inclusive approach that would not only enhance environmental protection for the country but also respect social values. The outcomes of some of the current practices adopted to manage adverse environmental impacts were found to provide coping strategies that fit with the concepts of CSA. These, however, are still not very widespread. Specifically, farm management and technology practices such as the use of cover crops, crop rotation and inter-cropping, the use of improved seed varieties, tillage systems, water harvesting and management systems, improved pasture management systems and agroforestry are recommended. It is expected that, if consciously adopted by farmers in the region, the adverse impact of climate change and desertification on the people shall be greatly mitigated. Secondly, CSA shall enable farmers in the region to adapt effectively to the adverse impacts of climate change and desertification and hence, improve the wellbeing of rural farm households (which constitute the majority population) and help Northern Nigeria attain food security and sustainable development.

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Full Length Research Paper

Milk handling practices and its challenges in Borana Pastoral Community, Ethiopia

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A total of 132 randomly selected milk producing households (HH's) were interviewed to assess milk handling and its challenges. The average household HH size of respondents was 7.76 (0.3) persons per family. The average land holding per households was 2.91 (0.08) hectare (ha). Natural pasture is a common feed source in the studied area. The average number of dairy cows per household HH was 2.06 (0.01) and varied from 1 to 50 cows. Okkicha kebelle had the highest number (2.32) cows. The milking operation is usually conducted in the barn, in an open area and milking is performed twice a day (85%). All the studied households do not use towels for cleaning and drying cow's udder. Proper cleaning of milk handling equipment was not done in the majority (77.8%) of the pastoral households. The majority (83.34%) of the pastoral households use traditional dairy containers and the others (16.66%) make use of aluminium and plastics cans. The predominant washing practices (83.33%) were washing milk handling equipments by the use of water and leaves of shrubs. The results indicate that the milking and storage conditions was unhygienic, insufficient cleaning of milk handling equipments and poor quality water usage were some of the basic determinant of milk quality assessed in the study area. These results appear to suggest the need for improved hygienic practice at different level of milk production in the pastoral community.

Key words: Milk handling, challenges, Borana, Pastoral community, Ethiopia.

INTRODUCTION

Ethiopia holds the largest livestock population in Africa. The total national milk production remains among the lowest in the world, even by African standard. The total annual milk production in Ethiopia from 10.7 million milking cows is estimated at about 3.8 billion liters, and this translates to an average production of 1.32 L/cow per day (CSA, 2013). In the Horn of Africa, pastoralists occupy large parts of arid and semi-arid lands of Ethiopia, Kenya, Somali, Djibouti, Eritrea, Sudan, Uganda, and Tanzania (FEWS NET/USAID, 2004). Together with agro-pastoralists they comprises significant proportions of national populations in each of these countries. Livestock

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ownership currently contributes to the livelihoods of an estimated 80% of the rural population. In the highlands, livestock are kept under settled or transhumant systems utilizing natural pasture. In the arid and semi-arid extensive grazing areas of the eastern, western, and southern lowlands, cattle, sheep, goats, and camels are managed in migratory pastoral production systems (FAO, 2005).

The estimated livestock population in pastoral districts also indicates that cattle are the prominent in population size (1,048,909) as an important specie and followed by goats (989,691), sheep (396,819) and camels (62,789) in order of population (CSA, 2013). The Borana breed, one of the multipurpose cattle breeds in Africa, was evolved, and is still widely reared by Borana pastoralists of Southern Ethiopia. According to Solomon (1999) the population of this breed living in the Borana pastoral areas is estimated at 1.7 million. Borana pastoralists' livelihoods depend predominantly on livestock and their products.

They practice a transhumance nomadic system which had been a primary survival strategy. The cattle herd is split into two groups: the '*Warra*' herd that comprises small number of animals specially milking cows and calves that are kept around the '*Olla's*' (permanent encampments); and the '*Forra'* herd that encompasses the majority of animals which are driven long distances in search of good pasture and surface water, irrespective of national boundaries (Coppock, 1994). As a pastoral community, milk is the main diet of the society in Borana Zone.

The physical infrastructure is poorly developed in areas where pastoralists live (FEWS NET/USAID, 2004). Milk and milk product handling in the area is more of a traditional type. There is little information available with regard to milk and milk products handling. Understanding the hygienic conditions of needed for milk and milk production and its challenges faced by the pastoral community in a given area is important to improve their wholesomeness and thereby provide quality and safe products to consumer as well as improve the income of farmers.

Therefore, the aim of the present study was to assess milk handling practices and its challenges in the Borana pastoral community.

MATERIALS AND METHODS

Study location

The study was carried out in Abaya district of Borana pastoral area of Oromia Regional State located at 366 km south east of Addis Ababa , between 03°37' 23.8" to 05° 02' 52.4" North and 37° 56' 49.4" to 39° 01' 101"East, in the Southern part of Ethiopia. The district represents a total area of 1205.28 km^2 and comprises 27 kebeles (the smallest administrative unit). The altitude ranges from 970 meter above sea level in the south bordering Kenya to 1693 meter above sea level in the Northeast. The climate is semi-arid, with which receives annual average rainfall ranging from 500 mm^3 in the south to over 700 mm^3 in the north. The area receives bimodal rainfall, where 56% of the annual rainfall occurs from March to May and 27% from mid September to mid-November (Coppock, 1994). Annual mean daily temperature varies from 19 to 24°C with moderate seasonal variation.

Data collection

The study was conducted from June 2010 to May 2011. Pastoral community of six Kebeles were selected from 27 Kebeles of Abaya district using purposive sampling procedures based on their geographical location, proximity to fresh milk, and socioeconomic characteristics for this study.

The selected kebeles's were Debeke, Dibbicha, Gollolcha, Ture Kejima, Okkicha and Wadye-Kejima. A total of 132 pastoral dairy households, 22 from each Kebele, were selected using simple random sampling technique for the survey study. A semi structured questionnaire which focused on the households attributes was used, including basic farm data (Socio-economic of characteristics, milk handling and hygienic practice) and other relevant information related to cow attributes such as number of lactating cow per households, udder preparation, animal housing systems and barn hygiene practices.

Data analysis

Descriptive statistics was used to evaluate the variables in the production, and milk handling practices using SPSS (2007) software (ver.16). The mean and percentage values of various parameters were compared across the studied kebeles.

RESULTS

Socio-economic characteristics of pastoral households

The average household HH size of the target respondents was 7.76 persons per family member size (Table 1). The average land holding of the overall study sites per household was 2.91 ± 0.08 ha.

Natural pasture, mineral licks, and cultivated pasture were common feed sources in the area. Okkicha Kebele had higher average grazing and crop land holding per households than the other rural kebeles (Figure 1). Both crop and fallow land was available only in Debeke kebele.

The average number of cows per household was 2.06 and varied from 1 to 50 cows. Among the studied six Kebeles, Okkicha had the highest number (2.32) of cows and the least (1.18) was for Debeke Kebele.

Educational status and religion of pastoral households

In this finding, there were more family members at elementary school level of education were higher than those at with higher educational level (Table 2), however, 58.3% of the respondents were illiterate. The majority of

Table 1. Mean (±SE) value of socio-economic characteristic of pastoral households of six Keble of Abaya District, Borana Pastoral Community.

Study Kebeles	HH's characteristics			
	Family size	Age structure	Land holding per HH^{-1} (ha)	Lactating cows per HH^{-1}
Gololicha	7.05(0.7)	45.73(2.2)	2.93(0.2)	2.27(0.2)
Debeke	7.14(0.5)	44.73(3.1)	3.28(0.2)	1.18(0.1)
Dibbicha	9.0(0.9)	48.95(2.4)	2.71(0.2)	2.24(0.2)
Ture-Kejima	7.43(0.5)	42.35(1.9)	2.83(0.2)	2.22(0.2)
Okkicha	7.91(0.6)	42.14(2.9)	3.09(0.2)	2.32(0.2)
Wadye-Kejima	8.09(0.8)	43.68(3.5)	2.63(0.3)	2.14(0.2)
MeanTotal (N=132)	7.76(0.3)	44.55(1.1)	2.91(0.08)	2.06(0.01)

N=Number of respondents of each Keble of HH's; SE = standard mean error.

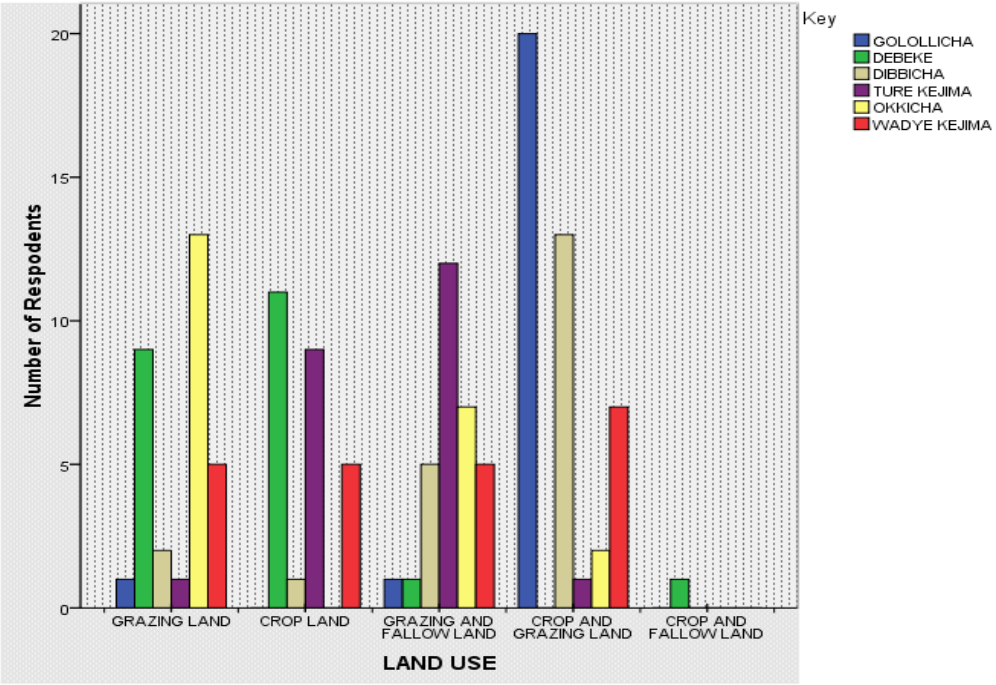

Figure 1. Land use pattern of the pastoral households of six Keble of Abaya District, Borana Pastoral Community.

the respondents (67.4%) were protestant Christian followed by Orthodox Christian.

Housing system and barn hygiene

According to the study, among the interviewed households, 50.1% shared the same house with their animals, while 49.9% used separate house for their cattle (Table 3). High proportion of the studied households in Okkicha (77.3%) and Dibbicha (72.3%) shared the same house with animals. On the other hand, 77.3% of the households in Debeke Kebele use separate housing.

About 15.9, 23.5 and 60.6% of households in the study kebeles were always cleaned barns, sometimes cleaned barns and never practice this, respectively.

Milking and hygienic practices

The study showed that the milking operation is generally conducted in the barn, in at home and an open area. It is also performed two times a day in nearly 85% of the households (Table 4). In general, the udder was not prepared properly (Table 5) and furthermore, in some of the households HH the milker inserts their fingers into the milk to moisten the teat whenever it got dry while milking. The milker does not wash hands pre-milking. Milkers they

Table 2. Educational status and religion of pastoral households (HH's) of six Keble of Abaya District, Borana Pastoral Community.

Parameter	N	%
Education level		
Illiterate	77	58.3
Grade 1-6	45	34.1
> Grade 1-6	10	7.6
Religion		
Protestant	89	67.4
Orthodox Christian	31	23.5
Muslim	3	2.3
Traditional religion (*aba kullu*) follower's	9	6.8

N=Number of respondents of each Kebele HH.

Table 3. Dairy cattle housing system and barn hygiene of pastoral community of six Keble of Abaya District, Borana Pastoral Community.

Factors\level	Study Kebele {N (%)}						Overall (n=132)
	Gololicha	Debeke	Dibbicha	Ture kejima	Wadye Kejima	Okkicha	
Housing system							
Separate House	12 (54.6)	17(77.3)	6(27.3)	13(59.1)	9(40.9)	5(22.7)	62(49.9)
Mixed with home	10 (45.4)	5(22.7)	16(72.7)	9(40.9)	13(59.1)	17(77.3)	70(50.1)
Barn cleaning							
Clean always	2 (9.1)	1(4.6)	7(31.8)	0	6(27.3)	5(22.7)	21(15.9)
Clean some times	5 (22.7)	4(18.2)	3(13.6)	12(54.6)	7(31.8)	0	31(23.5)
No cleaning	15 (68.2)	17(77.2)	12(54.6)	10(45.4)	9(40.9)	17(77.3)	80(60.6)

N=Number of respondents of each Keble HH.

dry their hands using their own cloth, and the udder was not properly washed and dried (Table 6). All households do not use towels for cleaning and/or drying the cow's udder. The use of detergents for cleaning of milk equipment was not observed in the majority (77.8%) of pastoral dairy farmers. Most of pastoral households used tap, pond, and river water some times to clean milk equipment, udders and teats of cows, and wet the cow's teats to clean from soil and dirt (Table 7). About 81.5% of the pastoral dairy farmers used unboiled water for cleaning milk handling equipments.

Milk handling equipments and sanitary practices

In the surveyed pastoral area, households were observed using different milk containers for storing and processing milk. About 38.6% of the households mainly used *Cicu* followed by *Okkole* (27.3%) for milk storage. About 11.4% households used plastic jerry cans for milk processing and storage (Table 7, Figure 2). About 69.7% of the respondents washed their milk storage containers with cold water followed by warm water (12.9%). The other predominant practice (83.33%) washed milk handling equipments using leaves of shrubs of *Makana*, *Ejersaa* and *Dama Kessie*. Washing takes place once a day followed by drying and smoking milk handling equipments with plants stem. About 83.3% of the households smoke milk handling equipments with plants stem such as *Olean Africana* (Ejersa), *Tedecha gara* (*Acacia* spp) and *Balanities aegyptic* (Muka bedana) (Table 7).

DISCUSSION

Characteristics of pastoral dairy households

Land and livestock holding showed a relationship in the study areas where pastoral dairy households with larger landholding had higher livestock holding (Table 1). The majority of households have large area of crop, fallow land and large communal grazing land (Figure 1) which is important for livestock keeping. Livestock holding by the

Table 4. Milking frequency and its operation of six Kebele of Abaya District, Borana Pastoral Community.

Parameter	Study Kebeles {N (%)}						Overall (n=132)
	Gololicha	Debeke	Dibbicha	Ture kejima	Wadye Kejima	Okkicha	
Special place for milking							
Yes	2(9.1)	5(22.7)	1(4.6)	4(18.2)	0	8(36.36)	20(15.2)
Milking place							
In house	7(31.8)	5(22.7)	6(27.3)	9(40.9)	5(22.7)	2(9.1)	34(25.8)
In barn	8(36.4)	7(31.8)	7(31.8)	3(13.6)	10(45.5)	9(40.9)	44(33.3)
On open area	7(31.8)	10(45.5)	9(40.9)	10(45.5)	7(31.8)	11(50.0)	54(40.9)
Frequency of milking per day							
One time	5(22.7)	1(4.6)	0	0	4(18.2)	10(45.5)	20(15.2)
Two times	17(77.3)	21(95.4)	22(100)	22(100)	18(81.8)	12(54.6)	112(84.8)

N=Number of respondents of each Keble HH's.

Table 5. Hygienic practices followed during milking of **six Keble of Abaya District,** Borana Pastoral Community.

Hygienic practices	Study Kebele {N (%)}						Overall (n=132)
	Gololicha	Debeke	Dibbicha	Ture kejima	Wadye Kejima	Okkicha	
Pre -milking washing teat or udder							
Yes	2(9.1)	0	6(27.3)	0	5(22.7)	2(9.1)	15(11.4)
Teat or udder washing by							
Cold water	9(40.9)	7(31.8)	11(50)	0	0	12(54.6)	39(29.6)
Warm water	3(13.6)	1(4.6)	0	3(13.6)	0	6(27.3)	13(9.9)
No practices	10(45.5)	14(63.6)	11(50)	19(86.4)	22(100)	4(18.1)	80(60.5)
Pre -milking drying teat or udder							
Yes	4(18.2)	5(22.7)	8(36.4)	6(27.3)	0	7(22.7)	30(22.7)
Pre- dipping of teat or udder							
Yes	7(31.8)	4(18.2)	5(22.7)	2(9.1)	6(27.3)	3(13.6)	27(20.5)
Post -dipping of udder or teat							
Yes	2(9.1)	0	3(13.6)	5(22.7)	7(31.8)	4(18.2)	21(15.9)

N=Number of respondents of each Keble households.

respondents is quite high and they keep them for different purposes such as milk, meat and traction. The result shows that most respondents have low level of education (Table 2) which may have an influence on implement improved agricultural practices and good use of agricultural resources in the area. Education is an important entry point for empowerment of the rural communities and also an instrument to sustain development. This could have significant importance in identifying and determining the type of development and extension the service approaches. The role of education is obviously affecting households income, adopting technologies, demography, health, and as a whole the socio-economic status of the family.

Housing and barn hygiene

The environment in which dairy cows are kept has an effect on their health and welfare. Designing clean, comfortable housing, which is cheaper to maintain, is a key in determining the health and longevity of the dairy cow on the farm. Associations between clean barn and clean udder of cows, an index of environmental sanitation

Table 6. Sanitary practices followed by the milker of six Keble of Abaya District, Borana Pastoral Community.

Hygienic practices	Study Kebele {N (%)}						Overall (n=132)
	Gololicha	Debeke	Dibbicha	Ture kejima	Wadye Kejima	Okkicha	
Before milking hand washing by							
Cold water	4(18.2)	8(36.4)	5(22.7)	0	8(36.4)	9(40.9)	34(25.8)
Warm water	2(9.1)	0	2(9.1)	5(22.7)	2(9.1)	5(22.7)	16(12.1)
No practices	16(72.7)	14(63.6)	15(68.2)	17(77.3)	10(45.5)	8(36.4)	82(62.1)
Hand washing before milking							
Yes	1(4.6)	2(9.1)	8(36.4)	0	4(18.2)	6(27.3)	21(15.9)
Hand drying after wash							
No drying	3(13.6)	7(31.8)	9(40.9)	7(31.8)	0	5(22.7)	31(23.5)
Own cloth	19(86.4)	15(68.2)	13(59.1)	15(68.2)	22(100)	17(77.3)	101(76.5)

N = Number of respondents of each Keble households.

Table 7. Sanitary practices related to milk handling equipments performed in the pastoral community of Abaya District, southern Ethiopia.

Hygienic practices	Study Kebele {N (%)}						Overall (n=132)
	Gololicha	Debeke	Dibbicha	Ture kejima	Wadye Kejima	Okkicha	
Type of water source used							
River water	9(40.9)	5(22.3)	7(31.8)	5(22.3)	8(36.4)	4(18.2)	38(28.8)
Pond water	8(36.4)	4(18.2)	6(27.3)	9(40.9)	3(13.6)	6(27.3)	36(27.3)
Deep well water	1(4.6)	5(22.3)	4(18.2)	-	2(9.1)	-	12(9.1)
Tap water	2(9.1)	6(27.3)	2(9.1)	5(22.3)	7(31.8)	7(31.8)	29(21.9)
Rain water	2(9.1)	2(9.1)	3(13.6)	3(13.6)	2(9.1)	5(22.3)	17(12.9)
Milk storage containers							
Cicu (made from woven grass, small)	5(22.7)	7(31.8)	8(36.4)	12(54.5)	9(40.9)	10(45.5)	51(38.6)
Aluminum cans	1(4.6)	3(13.6)	-	1(4.6)	2(9.1)	-	7(5.3)
Okkole(made from woven grass)	4(18.2)	6(27.3)	10(45.5)	3(13.6)	6(27.3)	7(31.8)	36(27.3)
Gorfa (traditional dairy utensil)	5(22.7)	4(18.2)	3(13.6)	4(18.2)	4(18.2)	3(13.6)	23(17.4)
Plastic cans	7(31.8)	2(9.1)	1(4.6)	2(9.1)	1(4.6)	2(9.1)	15(11.4)
Washing milk storage containers by							
Cold water	12(54.5)	18(81.8)	13(49.1)	18(81.8)	13(49.1)	18(81.2)	92(69.7)
Warm water	4(18.2)	1(4.6)	4(18.2)	1(4.6)	3(13.6)	4(18.2)	17(12.9)
No practices	8(36.4)	3(13.6)	5(22.7)	3(13.6)	4(18.2)	-	23(17.4)
Smoking milk handling equipments							
Yes	16(72.3)	19(86.4)	18(81.8)	19(86.4)	20(90.9)	18(81.8)	110(83.3)
Smoking milk handling equipments by							
Ejersaa *(Olea Africana)*	15(68.2)	20(90.9)	22(100)	15(68.2)	17(77.3)	14(63.6)	103(78.0)
Makansa *(Croton macrostachyus)*	1(4.6)	1(4.6)	-	3(13.6)	2(9.1)	5(22.3)	12(9.1)
Muka bedana*(Balanities aegyptic)*	6(27.3)	1(4.6)	-	4(18.2)	3(13.6)	3(13.6)	17(12.9)

N = Number of respondents of each Keble households.

based on the amount of manure present on the cow and in her environment was a predictor for the occurrence of *coliform mastitis* (Bartlett et al., 1992). The majority of households (Table 3) reported that provision of proper shelter for animals has not been given the required attention. In almost all studied Kebeles, there was no practice of cleaning of barn rather than daily removal the feces. As a result, teats and udders of cows inevitably

Figure 2. Equipment used for milking, storage and transportation of six Keble of Abaya District, Borana Pastoral Community.

become soiled which lead to contamination of milk during milking (Slaghuis, 1996). Therefore, a proper animal housing system and barn hygiene practices might play a key role for controlling microbial quality and safety of raw cow milk

Milk handling and hygiene

Production of milk and various dairy products takes place under rather unsanitary conditions and poor production practices. At the production level, milking and handling of milk is a concern because personnel as well as milking equipment hygiene are insufficient among the milk handlers (Mogessie, 1990; Zelalem and Faye, 2006). Post harvest losses are associated with poor handling, contamination, low level of technology applied in the conservation of milk to extend its shelf life and lack of market (Getachew, 2003). In addition to this fact, contamination of milk during milking and handling is high due to the use of unclean equipment and water for washing, personnel not washing hands with soap and potable water (Almaz et al., 2001). Besides, there is lack of proper cleaning of udder, test for abnormalities of milk and lack of cooling facilities. These could lower milk quality and have significant concern on public health (Jayarao and Wang, 1999; Jayarao et al., 2004). Fresh milk is stored in Gorfa, Okkole, Cicu, aluminum cans and plastic jerry-cans (Figure 2) which are smoked for preservation except the equipments made up of plastics, to enhance taste and odour of the product, and to disinfect the vessels, but they are very difficult to clean and to keep clean. As reported by Ashenafi and Beyene (1994), unsmocked containers tend to have high microbial contaminants than the smocked containers. In general, this study revealed that hygiene standards among pastoral dairy households are very poor starting with personal hygiene to equipment used for milking, storage and transportation. Equipment used for milking, storage and transport include mainly traditional gourds, plastic jerry-cans and in few numbers aluminum cans. Traditional Gourds, which are usually smoked after usage, pass hygiene standards however; the milk is often transferred to plastic jerry cans and contributes to milk spoilage as they are difficult to clean (Gilmour, 1999; Bekele and Molla, 2000).

Conclusions

This study found that the majority of the pastoral households used traditional dairy containers. The predominant practice was washing milk handling equipments by the use of water and leaves of shrubs. The high incidence of dairy animals diseases, unhygienic conditions of milking and storage processes, transferring of milk into different containers, use of insufficiently cleaned milk equipment and the use of unclean water are basic determinants of milk quality and the hygienic practices followed by the milk producing households in the pastoral community. These results appear to suggest the need for improved hygienic practice of milk production.

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Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Estimates of genetic parameters in F_4 – F_5 soybean populations resistant to Asian soybean rust

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The objective of the present study is the evaluation of genetic parameters in F_4 and F_5 soybean populations from two crosses, which are potentially resistant to Asian soybean rust. The genotypes were developed from the cross between parents, which were resistant and susceptible to the disease, and totaled 137 genotypes in generation F_4 and 283 genotypes in F_5. The experimental design was augmented blocks with two checks between the treatments. The following agronomic characters were evaluated: plant height at maturity, first pod insertion height, number of nodes and branches, agronomic value, lodging, number of pods and seeds per plant and seed production. After the genotypes were submitted to analyses of variance, heritability, and selection gains, it was observed that Cross 1 had superior progenies, which were potentially resistant to Asian soybean rust and also had good productivity.

Key words: *Glycine max*, genetic improvement, heritability, selection gains, productivity.

INTRODUCTION

The perspective for soybeans is excellent at both the national and world levels. Brazil cultivated a total grain area of around 53.26 million hectares during the 2012/13 crop season, 4.7% higher than for 2011/12, corresponding to an area increase of 2.38 million hectares. The total soybean area [*Glycine max* (L) Merrill] in Brazil is 27,721.60 million hectares and it increased by 10.7%, or 2.68 million hectares, compared to the previous crop. Productivity was an average 2,938 kg/ha, a 10.8% increase compared to 2012, which was a record, with the estimated production being 81,456.10 million tons, a 22.7% increase over the previous crop (Conab, 2013).

This significant development of the soybean crop can be attributed to Genetic Improvement Programs, focusing on the selection of progeny, which have desirable characteristics, including the production of erect plants of a suitable height, facilitating mechanical harvesting; higher grain yield, requiring a smaller area for high production; resistance to diseases and insects, reducing production; resistance to diseases and insects, reducing losses; oil and protein content for foodstuffs and also

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biodiesel production; as well as early maturation and drought resistance to better adapt to different regions and adverse climates (Sediyama et al., 2009). The selection of superior genotypes in a Genetic Improvement Program is based on the estimate of genetic and phenotypic parameters, together with an experimental design and a suitable selection method. This constitutes a solid basis for determining the best performances of the agronomic characters to be studied, consequently resulting in potentially better selection (Falconer, 1987).

The objective of the current study was to evaluate genetic parameters from selection in F_4 and F_5 soybeans, originating from two crosses and which were potentially resistant to Asian soybean rust.

MATERIALS AND METHODS

Experimental site characteristics

The trial was done during the 2009/10 and 2010/11 crop seasons, represented by the F_4 and F_5 generations respectively, on the Teaching, Research and Extension Farm (FEPE) of the University of Agricultural Science and Veterinary - UNESP, Jaboticabal Campus São Paulo state (latitude 21° 14' 05'' S, longitude 48º 17' 09'' W, altitude 615.01 m). The predominant soil type is a Red Eutroferric Latosoil and the climate is subtropical (Cwa).

The area was plowed and harrowed twice and all the cultural practices recommended for soybeans were applied (Embrapa, 2011). The experimental design was augmented blocks, with 137 genotypes in the F_4 and 283 genotypes in F_5 generation, and two checks between them. Each family was derived from the threshing of an individual plant. Sowing was manual in 5 m long rows, 0.5 m apart, resulting in a planting density of around 20 seeds per linear meter.

The checks used were the comercial cutlivars: MGBR 46–Conquista and Coodetec-219. Eight plants were evaluated per plot.

Genetic material

The genotypes used were developed from crosses between parents, which were resistant (R) and susceptible (S) to Asian soybean rust: PI 200526 Shiranui (R) x COODETEC 205 (S) and PI 200456 (R) x MG/BR–46 (Conquista) (S) (Costa, 2008). The parents resistant to the pathogen correspond to the introduction of exotic plants (PI's) and the susceptible plants are cultivars already adapted to Brazilian conditions, with a good agronomic performance for grain-producing characters.

The genotypes are in the F_4 and F_5 generations and were selected according to their performance for Asian rust resistance, previously evaluated in a greenhouse.

Agronomic characters evaluated in the F_4 and F_5 generations

The genotypes were evaluated and selected for the main soybean agronomic characters in the R_8 stage, according to the Fehr and Caviness (1977) scale: Plant height at maturity (PHM) – the distance in cm between the soil surface and the main stem tip at maturity; first pod insertion height (IHP) – distance in cm between the soil surface and insertion of the first pod; agronomic value (AV) – evaluated using a visual scale varying from 1 (poor plants) to 5 (excellent plants), with the ranking being representative of a group of visual characters: architecture, number of full pods, vigor and health, premature opening of the pods, lodging and foliar retention at maturity; lodging (L) – character evaluated using a visual scale varying from 1 (all plants in the plot erect) to 5 (all plants lodged); number of nodes (NN), the number of nodes on the plants at maturity; number of branches (NB), the number of branches per plant at maturity; number of pods per plant (NPP), the total number of pods on the plant; number of seeds per plant (NSP), the number of seeds produced per plant, and seed production per plant (SP), weight in grams of grain produced per individual plant.

The rankings attributed to the L and AR characters were transformed to $\sqrt{x+0.5}$ to obtain more normally distributed data.

Statistical analyses

All the analyses were done using the Genes Software, 2008 version (Cruz, 2008). Analyses of variance were done for each characteristic evaluated, for each control and for each check and the segregated population (family) of each crossing in the two generations, with the statistical model adopted according to Cruz (2001). The statistical model for the analysis of variance was: $Y_{ij} = \mu + f_i + e_i + p_{ij} + \delta_{ij}$, where Y_{ij} is the observation corresponding to the j^{th} plant of the i^{th} famíly; μ is the overall mean of the generation, whether it be the check or the family; with f_i being $f_i \sim$ NID (0, $\hat{\sigma}^2_g$) the genetic effect attibuted to the i^{th} famíly, with i = 1,2...n; e_i with $e_i \sim$ NID (0, $\hat{\sigma}^2_e$) being the environmental effect between rows of a check or families; p_{ij} with $p_{ij} \sim$ NID (0, $\hat{\sigma}^2_w$) being the genetic effect attributed to the j^{th} plant of the i^{th} family, with j = 1,2...n; δ_{ij} and the environmental effect between plants within rows of a check or family.

Thus, with the data between and within the plots of the checks and the segregated lines, the phenotypic, genotypic, environmental and additive components were estimated, which also permitted the estimation of the heritability coefficients in the narrow and broad sense, between and within the families, according to the following expressions (Cruz, 2001):

(a) Heritability in the broad sense:

Between families: $h^2_{Ae} = \frac{\hat{\sigma}^2_{ge}}{\hat{\sigma}^2_{Ef}}$; - Within families: $h^2_{Ad} = \frac{\hat{\sigma}^2_{gd}}{\hat{\sigma}^2_{Df}}$;

(b) Heritability in the narrow sense:

Between families: $h^2_{Re} = \frac{\hat{\sigma}^2_{a\ between}}{\hat{\sigma}^2_{Ef}} = \frac{2F\,\hat{\sigma}^2_a}{\hat{\sigma}^2_{Ef}}$;

Within families: $h^2_{Rd} = \frac{\hat{\sigma}^2_{a\ within}}{\hat{\sigma}^2_{Df}} = \frac{(1-F)\,\hat{\sigma}^2_a}{\hat{\sigma}^2_{Df}}$;

Total: $h^2_{R\ total} = \frac{\hat{\sigma}^2_{a\ total}}{\hat{\sigma}^2_{f\ total}} = \frac{(1-F)\,\hat{\sigma}^2_a}{\hat{\sigma}^2_{f\ total}}$;

Where: $\hat{\sigma}^2_{Df}$: phenotypic variance between plants within the families; $\hat{\sigma}^2_{gd}$: genotypic variance between plants within families; $\hat{\sigma}^2_{ed}$: environmental variance between plants within families; $\hat{\sigma}^2_{Ef}$: phenotypic variance between families; $\hat{\sigma}^2_{ge}$: genotypic variance between families; F: coefficient of endogamy, varying from 0.87 and 0.93 for the F_4 and F_5 generations, respectively; $\hat{\sigma}^2_a$: additive variance.

The calculations for the selection gain or selection response were made as follows (Falconer and Mackay, 1996): $GS = h^2S$ where, GS: selection gain or selection response; h^2: heritability coefficient; $S = (X_{Si} + X_{Oi})$, with S the selection differential; X_{Si} the mean of the individuals selected for the character i and X_{Oi} the original mean of

Table 1. Summary of analysis of variance for the characters: plant height at maturity (PHM), first pod insertion height (IHP), number of nodes (NN), number of branches (NB), number of pods per plant (NPP), number of seeds per plant (NSP) and seed production (SP), in F_4 and F_5 soybean progenies for Crosses 1 and 2, at Jaboticabal, São Paulo state.

Source of variation	PHM	IHP	NN	NB	NPP	NSP	SP
Generation F_4							
Cross 1							
QM	77.00^{ns}	12.58*	0.86^{ns}	0.32^{ns}	92.33^{ns}	189.35^{ns}	14.37*
Mean	79.85	15.73	10.87	2.57	67.06	92.97	12.03
Phenotypic variance	77.00	12.58	0.86	0.32	92.33	189.35	14.37
Environmental variance	62.17	5.21	0.48	0.19	43.07	90.36	5.16
Genotypic variance	14.83	7.38	0.38	0.13	49.25	98.99	9.21
CVg (%)	4.89	18.55	5.80	14.56	10.49	10.77	24.91
Ratio CVg/Cve	0.49	1.19	0.88	0.84	1.07	1.05	1.34
Cross 2							
QM	31.12**	11.43**	0.80*	0.36**	56.64*	96.09**	4.90**
Mean	88.68	23.75	12.09	3.00	66.64	90.29	10.62
Phenotypic variance	31.12	11.43	0.80	0.36	56.64	96.06	4.90
Environmental variance	6.44	1.09	0.23	0.03	15.35	12.37	0.79
Genotypic variance	24.69	10.33	0.57	0.33	41.29	83.72	4.11
CVg (%)	5.66	13.39	6.29	19.01	9.79	10.33	19.11
Ratio CVg/Cve	1.96	3.07	1.56	3.48	1.64	2.60	2.29
Generation F_5							
Cross 1							
QM	237.71**	20.62*	3.30*	0.86*	322.60**	1318.67**	21.22**
Mean	67.86	13.05	9.51	2.99	57.80	113.85	12.03
Phenotypic variance	237.71	20.62	3.30	0.86	322.60	1318.67	21.22
Environmental variance	69.48	11.54	2.01	0.45	129.62	462.53	4.35
Genotypic variance	168.24	9.08	1.28	0.41	192.98	856.15	16.88
CVg (%)	19.97	26.51	12.46	20.71	23.67	25.52	33.23
Ratio CVg/Cve	1.56	0.89	0.80	0.95	1.22	1.36	1.97
Cross 2							
QM	163.53**	25.48^{ns}	4.25*	0.57^{ns}	488.18**	1297.36**	33.70**
Mean	77.81	20.34	11.25	3.41	55.56	102.47	12.93
Phenotypic variance	163.53	25.48	4.25	0.57	488.18	1297.36	33.70
Environmental variance	6.83	9.83	0.33	0.33	30.17	78.17	0.95
Genotypic variance	156.70	15.65	3.92	0.23	458.01	1219.19	32.76
CVg (%)	17.05	20.78	18.72	13.35	39.30	36.30	43.31
Ratio CVg/Cve	4.79	1.26	3.43	0.84	3.90	3.95	5.88

QM = mean squared; CVg = Genetic Variation Coefficient; CVe = Experimental Variation Coefficient; * and ** Significance at the 5 and 1% probability levels using the F test, respectively.

the population, considering a selection intensity of 25%.

RESULTS AND DISCUSSION

Lodging and agronomic value characteristics were not analyzed statistically because the rankings attributed by plant breeders were subjective. The plants were evaluated in the field and only those which showed suitable phenotypes for these characteristics were selected.

The analysis of variance of the F_4 generation, Cross 1 (Table 1), showed that the characters first pod insertion height and seed production per plant showed significant differences between the genotypes (P≤5%), not observed for the remaining characters. The characters number of nodes and number of pods per plant in Cross 2 were significantly different (P≤5%) as also were plant height at

maturity, first pod insertion height, number of branches, number of seeds per plant and seed production per plant (P≤1%). This demonstrates a higher variability in the Cross 2 genotypes, making possible greater genetic gains with the selection.

The genetic variation coefficients in the two crosses had values below 25%, including the quantitative characters, which were near the limit of up to 20% for cultivars in advanced generation of inbreeding (Brasil, 1998). This indicated good experimental precision, that is, a narrow band of values for each character, even the quantitative ones, highly influenced by the environment, lying within a normal distribution curve. The CVg/CVe ratios were close to 1 for most characters, favoring the selection of superior genotypes (Cruz and Regazzi, 1997).

There were significant differences for the characters first pod insertion height, number of nodes and number of branches (P≤5%) and also for plant height at maturity, number of pods per plant, number of seeds per plant and seed production per plant (P≤1%) in Cross 1 of the F_5 generation (Table 1). The results of Cross 2 were similar to those of Cross 1 but first pod insertion height and number of branches were not significant. The values of the genetic variation coefficient in Cross 1 were within acceptable limits, except for seed production per plant (33.23%). In Cross 2, the characters number of pods per plant, number of seeds per plant and seed production per plant had values of 39.30, 36.30 and 43.31, respectively, higher than ideal due to the fact that they are highly influenced by the environment and, therefore, subject to a wider range of values. These characters also showed a lower experimental precision when compared to the previous generation, which was caused by environmental change. The CVg/Cve ratio was higher than 1 in both crosses, once again demonstrating good selection results.

The genetic variance in both generations of Cross 2 was higher than the environmental variance, demonstrating the predominance of genetic componentes compared to environmental ones, and indicating favorable conditions for improving the characters under evaluation. According to Burton (1952), the genetic variation coefficient (CVg) should be associated with heritability in order to compare the genetic variability of different populations and characters and help in predicting genetic gain. Thus, high values for the genetic variation coefficient generate high values of heritability and are associated with greater genetic variability, greater selective accuracy and more possibilities for successfully selecting soybean lines with better grain yield (Cargnelutti Filho et al., 2003; Storck and Ribeiro, 2011).

When comparing broad heritability values between and within famiies in the analysis of the heritability coefficient in Cross 1, in generation F_4 (Table 2), the characters first pod insertion height (0.60), number of nodes (0.39) and number of branches (0.40) showed the highest values for broad heritability between the families, whereas the number of pods per plant (0.57), number of seeds per plant (0.54) and seed production per plant (0.67) were superior for broad heritability within the families. However, in an Improvement Program, the total restricted heritability is considered the most reliable for character heritability since it shows additive genetic variance as a component. This is the main reason for the parental similarity, and shows the genetic properties observed in a population and its response to selection. Its job is to orient the relative quantity of genetic variance used in improvement (Falconer, 1987). The highest estimates of total restricted heritability were for the characters plant height at maturity (0.14), number of nodes (0.19) and number of branches (0.13), whereas the lowest values were for first pod insertion height (0.05), number of pods per plant (0.07), number of seeds per plant (0.08) and seed production per plant (0.07).

The heritability in the broad and narrow senses between families in Cross 2 were superior to the heritability within families, indicating that the genetic fraction is more important in determining the phenotypic differences between genotypes than the differences between individuals of the same family (Backes et al., 2002). The highest values obtained for total restricted heritability between the genotypes were for plant height at maturity (0.38), first pod insertion height (0.31) and number of branches (0.28) and the lowest estimates continued to be for the characters directly linked to production. This was expected since they are quantitative characters, controlled by a large number of genes and, therefore, has a greater environmental influence (Backes, 2002; Mauro et al., 2000; Toledo et al., 2000).

Once again, in generation F_5 (Table 2), heritabilities in the broad and narrow senses were greater between than within families. All the characters in Cross 2 had values higher than 50%, indicating that the genetic contributions are more pronounced than those attributed to environmental factors in the phenotypic expression of the character (Falconer, 1987). The characters with the highest values in total restricted heritability in Cross 1 were plant height at maturity (0.52) and number of nodes (0.27), whereas the lowest estimates were for number of seeds per plant (0.10) and seed production per plant (0.08). The characters plant height at maturity (0.85), number of nodes (0.49) and number of seeds per plant (0.24) in Cross 2 had the highest values for the coefficients of total restricted heritability, with number of branches (0.06) and seed production per plant (0.06) having the lowest values.

When comparing the two crosses and the two generations it can be observed that the values for restricted heritabilities within the families are always less than those for the broad heritability within the families. This is due to the restricted heritability being estimated by the additive variance, which, in turn, represents only a

Table 2. Estimates of Heritability Coefficients in the broad and narrow senses, between and within families, and total restricted for the characters: Plant height at maturity (PHM), first pod insertion height (IHP), number of nodes (NN), number of branches (NB), number of pods per plant (NPP), number of seeds per plant (NSP) and seed production (SP), in F_4 and F_5 soybean progenies for Crosses 1 and 2, at Jaboticabal, São Paulo state.

Source of variation	PHM	IHP	NN	NB	NPP	NSP	SP
Generation F_4							
Cross 1							
h^2_{Ae}	0.21	0.60	0.39	0.40	0.52	0.50	0.63
h^2_{Ad}	0.25	0.51	0.09	0.06	0.57	0.54	0.67
h^2_{Re}	0.17	0.11	0.36	0.35	0.12	0.14	0.12
h^2_{Rd}	0.08	0.02	0.05	0.03	0.02	0.02	0.02
h^2_{Rt}	0.14	0.05	0.19	0.13	0.07	0.08	0.07
Cross 2							
h^2_{Ae}	0.76	0.84	0.75	0.94	0.75	0.86	0.83
h^2_{Ad}	0.29	0.39	0.36	0.21	0.65	0.71	0.52
h^2_{Re}	0.63	0.57	0.40	0.72	0.12	0.11	0.14
h^2_{Rd}	0.11	0.08	0.05	0.06	0.02	0.01	0.01
h^2_{Rt}	0.38	0.31	0.19	0.28	0.06	0.05	0.06
Generation F_5							
Cross 1							
h^2_{Ae}	0.54	0.34	0.38	0.53	0.58	0.67	0.79
h^2_{Ad}	0.02	0.15	0.04	0.20	0.24	0.47	0.63
h^2_{Re}	0.58	0.25	0.38	0.28	0.28	0.21	0.16
h^2_{Rd}	0.23	0.02	0.06	0.01	0.01	0.01	0.01
h^2_{Rt}	0.52	0.14	0.27	0.12	0.11	0.10	0.08
Cross 2							
h^2_{Ae}	0.92	0.55	0.72	0.77	0.99	0.96	0.99
h^2_{Ad}	0.14	0.26	0.30	0.40	0.67	0.36	0.78
h^2_{Re}	0.95	0.36	0.65	0.15	0.30	0.54	0.13
h^2_{Rd}	0.35	0.03	0.11	0.01	0.02	0.03	0.01
h^2_{Rt}	0.85	0.20	0.49	0.06	0.14	0.24	0.06

h^2_{Ae} = Broad heritability between families; h^2_{Ad} = Broad heritability within families; h^2_{Re} = Restricted Heritability between families; h^2_{Rd} = Restricted Heritability within families; h^2_{Rt} = Total restricted Heritability.

part of the genotypic variance used in calculating broad heritability. This relationship is extremely valuable because it shows the importance of predicting gain based on restricted heritability, and this is even more important when there is an interest in comparing the potentials of different populations, which is the objective of this study (Backes et al., 2002).

The analysis of the selection gain estimates in generation F_4 (Table 3) demonstrates that in Crosses 1 and 2 mass gains are superior when compared to selection gains between and within (GSed%) families for most of the characters, except for number of nodes and number of branches in Cross 1.

The highest values in selection mass gains in Cross 1 were for the characters number of branches (9.74%), number of pods per plant (6.20%) and seed production per plant (7.16%). Considering the primary production characters (number of pods per plant and seed production per plant), selecting better genotypes for this character suggests that greater indirect productivity can be achieved, it was mentioned by Vianna et al. (2013) also. On the other hand, the biggest gains for Cross 2 were for the characters first pod insertion height (11.76%) and number of branches (19.44%). The importance for number of branches is that a plant with more branches means more pods and, consequently, a higher productivity (Navarro Junior and Costa, 2002).

There is no superiority for the mass gain compared to selection gains for generation F_5 between and within families in Cross 1 (Table 3). However, the same superiority in the previous generation can be observed for Cross 2 for the most characters, except for first pod insertion height, which is important for this character since first pod insertion height should not be higher than

Table 3. Estimates of selection gain between and within families, selection between and within families and mass selection for the characters: Plant height at maturity (PHM), first pod insertion height (IHV), number of nodes (NN), number of branches (NB), number of pods per plant (NPP), number of seeds per plant (NSP) and seed production (SP), in F_4 and F_5 soybean progenies for Crosses 1 and 2, at Jaboticabal, São Paulo state.

Generation F_4							
Cross 1							
Source of variation	**PHM**	**IHV**	**NN**	**NB**	**NPP**	**NSP**	**SP**
Cross 1							
MS	91.91	19.29	12.09	3.15	63.48	121.94	16.79
MO	79.85	15.73	10.87	2.57	67.06	92.97	12.03
GSe (%)	2.76	3.50	5.24	10.01	4.49	4.23	5.16
GSd (%)	0.53	0.53	0.51	0.91	0.75	0.71	0.97
GSed (%)	3.29	4.03	5.75	10.92	5.24	4.94	6.13
GSM (%)	3.89	4.20	5.23	9.74	6.20	5.71	7.16
Cross 2							
MS	93.97	28.33	13.15	3.75	56.65	102.49	13.40
MO	88.68	23.75	12.09	3.00	66.64	90.29	10.62
GSe (%)	4.32	10.43	3.99	16.92	1.38	1.65	3.91
GSd (%)	0.54	1.04	0.53	2.15	0.18	0.23	0.48
GSed (%)	4.86	11.47	4.52	19.07	1.56	1.88	4.39
GSM (%)	5.01	11.76	4.72	19.44	1.72	1.93	4.45
Generation F_5							
Cross 1							
MS	85.87	10.92	9.16	3.14	61.72	121.29	13.06
MO	67.86	13.05	9.51	2.99	57.80	113.85	12.03
GSe (%)	18.22	13.46	9.50	11.15	9.96	8.20	7.43
GSd (%)	2.80	1.10	0.76	0.64	0.70	0.66	0.61
GSed (%)	21.02	14.56	10.26	11.79	10.66	8.86	8.04
GSM (%)	17.51	9.89	8.08	6.69	6.53	5.85	5.21
Cross 2							
MS	90.51	25.11	13.46	4.48	84.93	142.05	20.86
MO	77.81	20.34	11.25	3.41	55.56	102.47	12.93
GSe (%)	22.58	12.64	18.66	-6.34	15.17	24.13	6.28
GSd (%)	2.84	0.45	1.29	-0.26	1.13	1.53	0.45
GSed (%)	25.42	13.09	19.95	-6.60	16.30	25.66	6.73
GSM (%)	30.00	12.00	20.38	-5.74	17.99	26.29	7.95

MS = Mean of selected individuals; MO = Original population mean; GS_e = Selection gain between families; GS_d = Selection gain within families; GS_{Ed} = Selection gain between and within families; GSM = Mass selection gain.

12 cm to avoid production losses (Sediyama et al., 1999).

The highest values of mass selection gain in Cross 1 were obtained for the characters plant height at maturity (17.51%), first pod insertion height (9.89%) and number of nodes (8.08%). The height of the soybean plant has a significant indirect effect on pod number and that is the reason taller plants are selected and with a suitable first pod insertion height due to the tendency for these plants to produce more pods and, therefore, be more productive (Peluzio et al., 2005).

However, when selecting for this character, mechanical harvesting must be taken into account and soybean plants should be between 60 and 120 cm tall (Rezende and Carvalho, 2007). According to Jiang and Elgli (1993), the character for the number of nodes also contributes indirectly to production since more nodes can result in more flowers per plant and, consequently, more pods. The highest values for the mass selection gain for Cross 2 were for the characters: Plant height at maturity (30.0%), number of nodes (20.38%), number of pods per plant (17.99%) and number of seeds per plant (26.29%). The values of selection gains for plant height at maturity in the second crop stood out and this second cross had high values compared to Cross 1 for most characters,

principally production characters.

Negative values were observed for number of branches, which is not desirable and this may be due to some environmental interference since stimulating the development of tall plants means that plants are less branched and have a tendency to lodge. This explains the inversion in values as well as showing that this character had a value considered high in the heritability estimate, thus resulting in low selection gain estimates.

With an analysis of the selection gain estimates it was possible to observe that the use of simple improvement methods, such as mass selection, gives significant results and is a satisfactory selection process, even considering characters governed by many genes and highly influenced by the environment, such as for number of pods per plant, number of seeds per plant and seed production per plant. Also, if the primary production characters are considered, which are those which determine selection success when the objective is a production increase, Cross 1 remained more stable with significant gains and a greater potential for obtaining superior progenies when compared to Cross 2.

Conclusions

1. The genotypes with potential for resistance to Asian soybean rust, which belonged to the two crosses, showed good agronomic field performance;
2. Cross 1 (PI 200526 Shiranui x COODETEC 205) was superior to Cross 2 (PI 200456 x MGBR–46 Conquista), and was the most promising for developing new cultivars.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Review

Plant disease management in India: Advances and challenges

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The responsibility of protecting food crops from diseases and pests in the challenging environment is rising with increase in human population and its needs. The crop losses due to pests are assessed to be ranging approximately between 10 to 30% of crop productions. Status and importance of various diseases have changed over the years in India. Awareness is needed to know the status of these problems and to develop management modules to protect these in eco-friendly manner. IDM is a multidisciplinary approach that seems promising to manage diseases effectively by integration of cultural, physical, biological and chemical strategies. Of the diverse components in IDM, biocontrol is important, but notwithstanding their known efficacy, biocontrol formulations have only a inadequate share in the national pesticide scenario. How to make biocontrol more effective, feasible and popular needs to be reviewed thoroughly. Development and use of molecular techniques for pathogen detection, resistance identification and cloning of genes for resistance seems very promising to realize the goal. So, further research thrust is needed in India to develop and utilize new novel technologies and strategies like gene cloning, recombinant DNA technology and other biotechnological and molecular modules to minimize the crop losses due to existing and new emerging diseases in the light of climate changes. Plant pathologists have a crucial role to play in this scenario. We have to be more proactive in our approach. Some of the current advances and emerging challenges in crop disease management in India are briefly discussed in this review.

Key word: Integrated disease management, biocontrol, India.

INTRODUCTION

India is known as growing economic giant but the benefits of this progress are mostly confined to urban or semi-urban areas. More than 65% of the population in the country lives in rural areas and depends on agriculture and related avenues for their sustenance. Hunger and poverty persists because of lack of work opportunities, thus inadequate income for farming communities. Indian agriculture, basically characterized as a means of subsistence, is changing fast as per market demands both domestically and international. Modern high input mono cropping based intensive agriculture has resulted in loss of biodiversity, outbreaks of pests and diseases, degradation of soil and water, which has ultimately led to stagnating agricultural production and productivity. Climatic changes are becoming a major factor in the present scenario (Kumar, 2013e).

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The crop yield losses, on field and during post harvest period, caused by pests, diseases and weeds are of paramount importance. The crop losses due to pests, diseases and weeds are approximately assessed to be ranging between 10 to 30% of crop productions. If we consider, on a average, crop loss of 20%, and the present gross value of our agriculture produce as Rs, 7 lakh crore, the loss comes to Rs. 1,40,000 crore, which is colossal (Kumar and Gupta, 2012). Even if we could save 50% by using plant protection, it will add Rs. 70,000 core additional income to our farmers. At a same time, when all of us are concerned about National Food Security, can the country afford these losses? Various type of direct and indirect losses caused by plant diseases include, reduced quality and quantity of crop produce, increased cost of production, threat to animal health and environment, limiting the type of crops/varieties grown, loss of natural resources and less remunerative alternatives adopted (Kumar and Saxena, 2009). In order to combat the losses caused by the plant diseases, it is mandatory to define the problem and seek solutions, At the biological level, the requirements are for fast and accurate identification of the causal organism, accurate estimates of the severity of diseases and its effect on yield, and identification of its virulence mechanisms. Disease may then be minimized by the reduction of the pathogen's inoculums, inhibition of the virulence mechanisms, and promotion of genetic diversity in the crop.

Success in disease management, as in most walks of life, depends on having right tools and the confidence to apply them. The key tool for disease management is knowledge and having knowledge gives the confidence. Diagnostic and advisory support systems are facing huge challenges in making relevant and effective knowledge and support available to farmers and market chains and ensuring that upstream researchers are informed of the real priority problems and issues requiring resolution.

Chemical pesticides have reduced crop losses in many situations, but even with a substantial increase in pesticide use, the overall proportion of crop losses and the absolute value of these losses from diseases appear to have increased over time (Kumar and Gupta, 2012). Nonetheless, an increase in pesticide use still appears to be profitable. Increased monoculture, reduced crop diversity and rotation, and use of herbicide have all increased vulnerability to diseases as well. Pathogens tend to develop resistance to pesticides, requiring higher use to sustain production. Inappropriate and excessive pesticide use led to increased and unnecessary disease out breaks and additional disease loss because of the inadvertent destruction of natural enemies of diseases, disease resistance and resurgence of secondary diseases. Ultimately, overuse of pesticides can reduce food production. Proponents with varying perspective on chemicals agree threat integrated disease management (IDM) must be science based and economically viable for farmers. The emphasis in on disease problems and preventing them form reaching economically damaging levels.

Host–plant resistance, natural plant products, biopesticides, natural enemies and agronomic practices offer a potentially viable option for IDM. They are relatively safe for the non target organisms and humans. Biotechnological tools such as marker assisted selection, genetic engineering, and wide hybridization to develop resistant crop cultivars will have a great bearing on future disease management programs. Disease modeling, decision support systems, and remote sensing would contribute to scaling up and dissemination of IDM strategies.

Plant pathology is challenging and an important science that deals with science of disease development and ability of managing diseases. Society, consumers and growers will only be able to continue to benefit from plant pathology if the discipline can evolve appropriate disease management schemes that can respond to the significant changes in agricultural practices in India; the ultimate goal being to produce more and safer food in sustainable agricultural systems that conserve natural resources and the environment. Information technology, communication and the integration of conventional and new technologies are essential and must be integrated by the modern practitioners of plant pathology into effective disease management schemes that can be implemented at the farm level. In view of this, a review article on current advances and emerging challenges in crop disease management in India should be viewed as very timely and appropriate.

Changing disease scenario

The status and importance of various diseases have changed over the years. Numerous diseases like papaya ring spot (papaya ring spot virus) and *phytophthora* diseases (*Phytophthora parasitica, Phytophthora palmivora, Phytophthora citrophthora* etc) have taken serious proportions. In 2008, there was flare up of neck blast and brown plant hopper of rice in Haryana causing losses up to 40% due to persistent and unprecedented rains at the flag end of monsoon season (Bambawale et al., 2008). Likewise, diseases with unfamiliar or complex etiology such as mango malformation and para wilt and grey mould of cotton and other diseases such as sheath blight of rice/maize, bract mosaic of banana, downy mildews in maize and several other crops have become devastating by virtue of evolution of virulent races or resurgence capabilities (Kumar and Gupta, 2012).

The nematode problems have taken their toll and with each year passing some of them are gaining momentum to decimate the entire cropping systems- the root knots, reniform and burrowing nematodes are important in different states; *Meloidogyne indica* is devastating the

kagzi lime in Gujarat, the root knot complex has similarly created serious situation with *Ceratocystis fimbriata* on pomegranate in Maharashtra, Karnataka and North Gujarat; the root knot is severely infesting mulberry plants which is adversely affecting the silk industry in Karnatka. Mostly, the reactions to outbreaks of diseases are in fire fighting mode and once the fire is doused, there is no follow up or recording the causes which had resulted in outbreaks. Even where the causes are investigated by eminent teams, their recommendations remain on paper.

Climate change

Climate change and the response of pathogens to changing conditions are matters for utmost priority for plant pathologists.

Research on impacts of climate change on plant diseases has been limited in India, although some striking progress has been made lately.

The rise in temperature at Kanpur may have been beyond the tolerance limit of *Aceria cajani*, the mite vectoring Sterility Mosaic Virus of pigeonpea, which could have influenced decline in the disease there. On the other hand, the weather factors might have shifted in favour of the vector at Bangalore that may have resulted in rise of the disease on the crop there (Kumar et al., 2013e). Climate change may have also influenced Phytophthora blight incidence at Kanpur and Pantnagar is mutually opposite directions (Kumar et al., 2013f).

While *Alternaria* blight is increasing on pigeonpea in Andhra Pradesh, Cercospora leaf spot is on the rise on the crop in Karnataka and Stemphylium blight is growing on lentil, chickpea, in some parts of India which could be due to the effect of climate change.

Root rot of oilseeds Brassica is an emerging threat for Rape seed – mustard production system, recently reported from the farmers' field in some pockets of the country. Some isolates of *Alternaria brassicae* sporulated at 35°C and several isolates had increased fecundity under higher RH, it seems that as per recent changes towards warmer and humid winters, being in line with current projections for future climate change (Waugh et al., 2003).

Global warming resulting in elevated carbon dioxide and temperature in the atmosphere could influence plant parasitic nematodes directly by interfering with their developmental rate, survival strategies and indirectly by altering host physiology. Studies have also demonstrated that the geographical distribution range of plant parasitic nematodes may expand with global warming spreading nematode problems in newer areas (Somasekhar et al., 2012).

There are also reports of upsurge in infestation by *Rotylenchulus* and *Pratylenchus* on several crops viz., chickpea, vegetables, etc (Somasekhar et al., 2012).

Seed pathology

Current emphasis for increased crop yields is to increase seed replacement rate. This requires seed health and rigorous seed health testing. Seed pathology involves the study and management of diseases affecting seed production and utilization, as well as management practices applied to seeds. Research innovations in detection of seed borne pathogens and elucidation of their epidemiology; advances in development and use of seed treatments; and progress towards standardization of phytosanitory regulations are to be strengthened (Chahal, 2012). With the globalization of agriculture, seed health testing is going to be mandatory for seed quality control. This needs highly sensitive, foolproof and quick methods for indexing seed borne pathogens. Immunodiagnostic and molecular technologies which are highly specific and sensitive test methods are yet to be simplified, standardized and commercialized in India for indexing seed borne pathogens of concern. There is a need to develop simple and efficient diagnostic test kits which can be defined as a commercially packaged system of the principal or key components of a seed health testing method (Vishunavat, 2009).

Tackling threat of Ug 99

Wheat rusts have been very imperative diseases of wheat worldwide. The large scale cultivation of wheat carrying a single gen Sr31 for protection against stem rust, over a large area proved to be a primer for the development of a new race virulent on this gene. Initially, this gene, used in breeding at CIMMYT, was selected as it was found allied with resistance to other two rusts like yellow (Yr 9) and brown rust (Lr 26). Achieving triple resistance with one gene was very striking for wheat breeders and this gene was used in breeding programmes all over the world. This gene was further found to be also linked with other positive traits like enhanced yield and adaptability over a array of environments. With the adoption of Sr 31 bearing cultivars, grown all over the world, the incidence and occurrence of stem rust became meager and sporadic. Thus, breeders stared to view stem rust of wheat as less of a threat. In such circumstances, it was anticipated that sooner or later the pathogen may heat back and this gene may lose its effectiveness. This was what precisely happened when a new race, popularly termed as Ug 99, emerged in highlands of Kenya and threatened wheat cultivation in the world (Sharma , 2012). The projection of its spread out of the continent, as happened in the past for Yr-9 virulence's, was a serious concern for the whole wheat community. Taking cognizance of this menace, global community was warned by Dr. Borlaug to take up suitable measure to embark upon the threat as stem rust has the potential to wipe out the crop. India, too, was at

risk country as it has been growing a cultivar carrying a single gene (Sr31) for protection, over a huge area. In addition to threat of Ug99, however same cultivar was also susceptible to yellow rust in the main wheat bowl of the country of the North West India. So, Indian wheat researchers need to address the threat of both yellow rust and Ug 99. Realizing the significance of wheat crop for the country, India adopted a range of activities that helped not only in assessing the damage to wheat crop but also helped in urging the wheat workers to replace the susceptible wheat with resistant one. The activities included screening against Ug99, extensive survey and surveillance, raising awareness of field workers, and developing new resistant stocks and identification of fungicides against Ug99. The first consignment for screening Indian wheat against Ug99 was sent to Kenya in 2002 and the majority of these varieties were found susceptible to Ug99. However, two genetic stocks were identified resistant. Subsequent screening of Indian wheat at Kenya revealed that some of the presently cultivated wheat's were resistant to Ug 99 (Prashar, 2012). So, it was a huge challenge for the country to replace varieties susceptible to both yellow and stem rusts. Second activity encompassed imparting training field workers to identify stem rust and distinguish susceptible response from resistant one. Thirdly, developing resistant genetic stocks with major genes and energized efforts to integrate adult plant resistance of polygenic kind were adopted. However, progress has been made with screening and developing resistant stocks, the challenge still remains on many vital areas *viz*, the role of stem rust in north hills, exploring new area of survival of wheat rust and reviewing epidemiology of wheat. For India, it remains a big challenge to replace susceptible cultivars with the resistant ones and exploring role of weather factors and grasses in survival of wheat rusts.

Plant parasitic nematodes

Plant parasitic nematodes are gaining significant importance worldwide due to their devastating effects on crops leading to major economic and social impacts. It is estimated that the 20 most important life sustaining crops undergo 10.7% yield losses due to nematodes, and other 20 economically important crops suffer 14% losses, the average amounts to 12.3%. While the average losses in developing nations including India is 14.6% (Ganguly and Dutta, 2012). According to trials in the 1960s, in Rajasthan alone the molya disease due to *Heterodera avenae* caused crop losses worth Rs. 400 million at current prices. Even ear cockle nematode, *Anguina tritici* caused less than 1% average loss of wheat amounts to Rs, 450 million at current prices. Similarly, root lesion nematode, *Pratylenchus* coffee cause damage worth of Rs. 200 million on coffee. At the global level root knot nematodes, *Meloidogyne incognita* is the major impediment in crop production as rarely any crop is free from its damage. In India, *M. incognita* cause colossal loss in vegetables like tomato, brinjal, okra, cucurbits etc. Rice root knot nematode, *M. graminicola* has emerged as a foremost predicament in rice wheat agro – ecosystem particularly in south –east Asia. Disease caused by nematodes are divided into subgroups according to their habitat and parasitic habit (sedentary, migratory, endo and ectoparasites).

Majority of the plant parasitic nematodes are ectoparasites include Xiphinema, Longidorus, Trichodorus Tylenchorhychus, Helicotylenchus, Hemicriconemoides, Paratylenchus etc. Some of the main migratory nematodes of above ground plant parts are *Ditylenchus dipsaci, D. angustus Aphelenchoides besseyi, Rhynchophorus palmarum, Bursaphelenchsu xylophilus* etc. Parasitic stages of some genera like *Tylenchulus* and *Rotylenchulus* partially enter roots of citrus and castor known as sedentary semi – endoparasites. While sedentary endo parasites like root knot and cysts complete their life cycle almost within the root itself followed by production of medium to large size galls in case of *Meloidogyne* incurring heavy damage. In addition to the direct damage, nematode also predispose plants to a variety of other pathogens particularly bacteria and fungi forming disease complexes. Some of them are tundu, vascular wilt, damping off, cortical rot, black shank etc. Other than that species of *Xiphinema, Longidorus* and *Trichodorus* are known to transmit soil borne viruses in plants leading to disease like grapevine fan leaf, raspberry ring spot, tobacco black ring etc. Under the changing climate and agricultural scenario, a sustainable management approach need to be adopted with an objective to uphold nematode population densities at the levels below the economic injury level or to lessen their levels such as to derive utmost profits out of the management cost is incurred (Ganguly and Dutta, 2012).

Emerging viral menace

Ever since the mosaic disease of tobacco was associated with a virus that is, Tobacco mosaic virus by the turn of 19^{th} century, more and more plant diseases were found to be caused by viruses. In India, several viral diseases of agriculturally important crops such as citrus, sugarcane and tobacco were identified namely tristiza in citrus, sugarcane mosaic in sugarcane and leaf curl in tobacco in 1920s and 1930s. Subsequently viral diseases of vegetables and ornamental, horticultural and field crops were studied. Many of these viral diseases have caused significant economic losses in several crops. A few emerging viral diseases which are of huge concern to our farmers are rice tungro, groundnut bud necrosis, sunflower necrosis, yellow mosaic of legumes, pigeonpea sterility mosaic, soybean bud blight, cotton leaf curl,

cassava mosaic, potato apical leaf curl, banana bunchy top, banana bract mosaic, papaya leaf curl, papaya ring spot, chlorotic leaf spot in peach, piper yellow mottle (Prabha and Baranwal, 2009). These new viral diseases are emerging because of intensive agriculture coupled with change in cropping system. This has allowed the prevalence of important virus vectors such as white fly and aphids throughout the year. It is important to develop short term and long term strategies for the management of viral diseases. There is an urgent need to develop diagnostics for detection of different viruses in field crops and vegetables. Emphasis is given on integrated disease management involving use of disease free planting material, agronomic practices to control vectors, development, and use of resistant varieties and timely diagnosis. Development and utilization of detection and diagnostic methods based on enzyme-linked immunosorbent assay (ELISA), polymerase chain reaction (PCR) and Microarray are gaining importance. Biotechnological tools have augmented conventional approaches in identification and isolation for resistant sources/genes and development of crops resistant to specific viruses through transgenic approaches. Viral resistant transgenic plants are obtained by inserting segments of viral nucleic acid into plant genomes that leads to silencing of genes of the virus that have homologous sequences, thereby making plants resistant (Singh and Malhotra, 2010).

Biotechnology in plant pathology

Diverse approaches in plant disease management have very much been influenced by the recent advances in molecular biology. Many biotechnological tools and techniques have been developed by using different plant pathogens as experimental materials. It has provided way to understand host pathogen correlation under diverse environment to give a novel look to this branch of science paradoxically viewed as ‘cut and burn’ technology. Different aspects are as follows:

(i) Molecular diagnosis of plant pathogens

Conventionally, cultural methods have been employed to isolate and identify potential pathogens. This is relatively slow process, often requiring skilled taxonomists to reliably identify the pathogen. However, over the last 30 years, several techniques have been developed which have found application in plant pathogen diagnosis; these include the use of monoclonal antibodies (Kohler and Milstein, 1975) and enzyme linked immunosorbant assay (ELISA) (Clark and Adams, 1977) and DNA based technologies, such as the polymerase chain reaction (PCR), which enable regions of the pathogen’s genome to be amplified by several million fold, thus increasing the sensitivity of pathogen detection. Furthermore, diagnostic PCR has been significantly improved by the introduction of second generation PCR, know as the real time PCR. It is now possible not only to detect the presence or absence of the target pathogen, but also to quantify the amount present in the sample. Enumerating the pathogen upon detection is crucial to estimate the potential risks with respect to disease development and provides a useful basis for diseases management decisions. The DNA micro array technology, originally designed to study gene expression and generate single nucleotide polymorphism (SNP) profiles is currently a new and emerging pathogen diagnostic technology and offers a platform for unlimited multiplexing capability. The fast growing databases generated by genomics and biosystematics research provide unique opportunities for the design of more versatile, high throughput, sensitive and specific molecular assays that will address the major limitation of the current technologies and benefit plant pathology. Finally, the so far restricted use of robotics to DNA technology will become economically feasible and thus accessible to farmers and will offer the possibility of using single DNA chip as practical tool for the diagnosis of hundreds of plant pathogens (Kumar, 2013d).

(ii) Analysis of molecular variability in plant pathogens

Characterization of genetic diversity in plant pathogens have been made feasible, beyond use of differential hosts, through diverse molecular techniques. Different molecular markers have been used in characterization of genetic diversity of plant pathogens. In most of the cases, these are RAPD (Williams et al., 1991), RFLP (Botstein et al., 1980), AFLP (Vos et al., 1995), SSR/ISSR (Guleria et al., 2007), ITS (Powell et al., 1996). The RAPD markers have been mostly used for characterization of fungal pathogens, followed by AFLP and ITS markers. This might be because of their ease and simplicity in use. Guleria et al. (2007) collected 19 *Rhizoctonia solani* isolates from rice growing regions of India, used two marker systems that is, RAPD and ISSR for molecular characterization of genetic variability. Of these two types of DNA markers, RAPD markers were able to detect more genetic variability when compared to ISSR markers.

(iii) Mapping of disease resistance genes using DNA markers

Molecular mapping can be used for direct selection of disease resistance genes for the use in plant breeding programmes. Commonly used markers are restricted fragment length polymorphism (RFLPs), amplified fragment length polymorphism (AFLPs), simple sequence repeats (SSRs), single nucleotide polymorphism (SNP) with predilection of PCR based markers. There is very few reports available form India which is required to be strengthened to support marker assisted selection (MAS)

in plant breeding for disease resistance.

(iv) Marker assisted pyramiding of disease resistance genes

Marker assisted pyramiding of disease resistance genes termed as 'Breeding by Design' can help to control the pathogen which recurrently and rapidly develop their new virulence. Efforts are made in India under Asian Rice Biotechnology network (ARBN) to pyramid resistance gene against bacterial blight of rice. Rice is among the first crops where marker assisted pyramiding of disease resistance genes was initiated. Rice varieties developed by using MAS have now been released for commercial cultivation for the first time in India. The variety amend as Improved Pusa Basmati-1 was developed by using conventional plant breeding approach integrated with MAS and two bacterial blight resistance genes Xa13 and Xa21 incorporated in Pusa Basmati-1(Gopalakrishnan et al., 2008). Another variety of rice resistant to bacterial blight was developed in non basmati type rice in India by using MAS. PCR based molecular markers were used in a backcross –breeding program to introgress three major bacterial blight resistance genes (Xa21, Xa13 and Xa5) into Samba Mashuri from a donor line (SS1113) in which all the three genes are present in a homozygous condition (Sundaram et al., 2008). These two reports successfully demonstrate the application of marker assisted selection for targeted introgression of BLB resistance genes into Basmati type and non-Basmati types varieties of rice in India. So, there is call for to take up such initiatives for other host pathogen system for control of serious loss causing diseases. Molecular markers can also help in assaying the germplasm for presence or absence of a particular disease resistance gene. Cloning of disease resistance genes by tagging approaches can identify the function of a specific genes by uncovering a specific pathotype. Initiation of his work will help to understand complex pathotype system of *Pyricularia* grisea (Jalali, 2008).

(v) Transgenics

Development of disease resistance through transgenic research is yet at primitive stage in India. Non availability of resistance to plant pathogens can be overcome by search and transfer of resistance genes from other sexually incompatible species which is possible using genetic engineering approach. It requires to first search for new genes which have broad spectrum resistance to pathogen population present in the region and then following transgenic approach, transferring of resistance to commercial varieties to achieve resistance, working at filled level. Disease resistance transgenic have been developed in banana and tobacco by transferring a synthetic substitution analogue of a short peptide, Maganin (Chakarbarti et al., 2003). Magainin is one of the earliest reported antimicrobial peptides from skin secretions of the African clawed frog. The peptide is not stable in its native form and, therefore, researchers modified it to express in foreign plant systems. Tobacco plants transformed with the peptide showed enhanced reisistance against *Sclerotinia sclerotium*, *Alternaria alternata* and *Botrytis cinerea*. Transgenic banana plants showed resistance to *Fusarium oxysporum f. sp. cubense* and *Mycosphaerella musicola* (Kumar and Gupta, 2012). However, it remains to be seen how these plants perform under natural disease conditions.

(vi) Application of genomics

Genomic has emerged as one of the frontier technologies during this century. Its application in different areas of plant pathology can be enormous in structural, functional or comparative genomics. Using high throughput genome sequencing technologies many plant pathogens are being sequenced world over. A list of pathogens which are at different stages of the genomic sequencing has been given by Jalali (2008).The massive genome sequence data being generated on different microorganisms can be used for simultaneous detection of multiple plant pathogens. The unique sequence from a wide range of pathogens could be used to develop micro-arrays for the simultaneous detection of large number of different strains. The probes and primers could be designed for differential detection of pathogens and their characterization at molecular level by using the unique sequence data of the pathogen's DNA.

(vii) Application of RNA interference

RNA interference (RNAi) has emerged as a powerful tool for battling some of the most notoriously challenging diseases caused by viruses, bacteria and fungi (Wani et al., 2013). RNAi is a mechanism for RNA guided regulation of gene expression in which double stranded ribonucleic acid (ds RNA) inhibits the expression of genes with complementary nucleotide sequences. The application of tissue specific inducible gene silencing in combination with the use of appropriate promoters to silence several genes simultaneously will result in protection of crops against destructive pathogens. RNAi application has resulted in successful control of many economically important diseases and pests in plants. Baum (2007) used RNAi to develop transgenic corn expressing ds RNA to silence genes of the corn root worm. Similarly, cytochrome p450 cy6AE14 genes of the cotton bollworm were silenced to disable the bollworm from feeding on gossypol in plants (Mao et al., 2007). In addition, RNAi approaches have also been used effectively to knockout the expressions of genes and to understand their biological functions (Anandalakshmi,

2013). The RNAi based technologies have tremendous potential in significantly reducing our reliance on chemical pesticides and thus pave way for the efficient, cost effective, eco –friendly alternative which will ensure a paradigm shift in pest management in India.

(viii) Post transcriptional gene silencing

The RNA silencing mechanism is also a powerful tool to develop crop species resistant to viruses. The expression of virus derived sense or antisense RNA in transgenic plants conferring RNA mediated virus resistance appears to induce a form of post transcriptional gene silencing (PGTS). It's a nucleotide sequence specific process that includes mRNA degradation, RNA silencing, an evolutionary mechanism protecting cells from pathogenic RNA and DNA, is viewed as an adaptive immune system of plants against viruses (Krishnaraj, 2013). Several lines of research indicate that RNA silencing can be induced locally and then spread throughout the organisms, and this aspect of the process likely reflects its role in viral defense.

Role of nanotechnology

Nanotechnology offers an imperative role in improving the existing crop management techniques. Generally only a very low concentration of agrochemicals have reached the target site of crops due to leaching of chemicals, degradation by photolysis, hydrolysis and microbial degradation. Hence, repetitive application is needed for effective control causing unfavorable effects such as rapid occurrence of resistance and soil and water pollution. Nano-formulated agrochemicals should be designed in such a way that they hold all necessary properties like effective concentration (with high solubility, stability and effectiveness), time controlled release in response to certain stimuli, improved target activity and less eco-toxicity with safe and easy mode of delivery. Therefore, an urgent need is to evaluate and develop natural, biodegradable, and environment safe nano-formulated compounds.

Biological control of plant diseases

The increased reflection on environmental concern over pesticide use has been instrumented in a large upsurge of biological disease control. Among the various antagonists used for the management of plant diseases, *Trichoderma* and *Pseudomonas* play a vital role. Among the various isolates of *Trichoderma viride, Trichoderma harzianum, Trichoderma virens* and *Trichoderma hamatum* are used against the management of various diseases of crop plants especially with dreaded soil-borne pathogens in India (Kumar et al., 2009). It has many advantages as a bio-control agent due to its high rhizosphere competence, ability to synthesize polysaccharide–degrading enzymes, amenability for mass multiplication, broad spectrum action against various pathogens and environmental friendliness (Kumar, 2013c). Fluorescent pseudomonads suppress the pathogens either directly through the production of various secondary metabolites or indirectly by inducing plant-mediated defense reactions. The crucial factor in the success of biological control by fluorescent pseudomonads is their ability to colonize the rhizosphere and their persistence throughout the growing season. Fluorescent pseudomonads are root colonizers because they occur in the natural habitat of rhizosphere and thus, when they are reintroduced to roots through seed or seed-piece inoculation, they colonize root surface profusely. Fluorescent pseudomonads suppress the pathogens by antibiosis through the production of various antibiotic substances such as 2,4-diacetyl phloroglucinol, phenazine-1-carboxylic acid, oomycin A, oxychlororaphine, pyoluteorin, pyrrolnitrin and pyocyanine. Siderophores are extracellular, low molecular weight substances which selectively complex iron with high affinity. Fluorescent pseudomonads produce siderophores such as pseudobactin and pyoverdine which chelate the iron available in the soil and make it unavailable to pathogen thus the pathogen dies for want of iron. In rice, seed treatment followed by root dipping and foliar spray with *Pseudomonas fluorescens* showed a higher induction of ISR against sheath blight pathogen, *R. solani* (Singh and Singha, 2004).While dealing with biocontrol we have to have a critical look at the following aspects which have been hindering its successful applications as bioprotectants. Greatest limiting factor is very short shelf life (4-6 months) under tropical and subtropical conditions. There is a strong need to increase the shelf life to make biological control application practically feasible. Sensitiveness of biocontrol agents (BCAs) to pH, temperature, moisture, substrates, etc are very important factors restricting their application. Modern biotechnological tools could be used to reduce these limitations (Mukhopadhyay, 2012). To date, 26 microbes have been included in the schedule to the insecticide act 1968 for production of microbial biopesticides. *T. viride*, *T. harzainum*, *Pseudomonas* sp., *Beauvaria bassiana, Metarrhizium anisopliae* and *Bacillus subtilis* are important biocontrol agents for management of various pest and diseases in India (Singh, 2012). However, their use is still limited to some selected states in our country. The major region for this phenomenon is the mushrooming of some fly –by-night spurious companies. This not only sow the seeds of doubt in farmers mind about the profitability of microbial pesticides but also the ill effect of these biopesticides.

The research on BCAs can only be fruitful when we commercialize and register the product based on superior

strains with the Central Insecticide Board (CBD) (Singh, 2012). Efforts must be on to work on the above issues by interdisciplinary approaches involving biotechnologists, microbiologists, plant pathologists, biochemists and also through strict control by government agencies.

Disease forecasting and monitoring

Plant disease forecasting and monitoring provides early information about the probable occurrence of a disease to facilitate chemical prophylaxis at appropriate time either to stop pathogen multiplication or further spread of the disease. Early information is essential to determine number of sprays and schedules to make economically sound disease control, and limit the chance of development of pathogen resistance to the pesticides. In developed countries pesticide use is warranted by well established monitoring, surveillance and forecasting system. It is generally done by established relationships between pathogen population and physical weather parameters like air temperature, rainfall, relative humidity, cloudiness, dry wetness or leaf wetness duration. Field monitoring for pre disease symptoms at susceptible stage and monitoring of favorable weather conditions make the basis of disease monitoring. Forecasting and monitoring of major air borne diseases have been relying on the knowledge on biology and ecology of the pathogen, quantitative seasonal studies over several years, season range, and variation in the population pattern, geographical distribution and weather records. Forecasting systems for potato late blight, apple scab, powdery mildew of mango, beer and rice blast are now available (Sinha and Banik, 2009) However, forecasting systems developed elsewhere could be adopted with local situation after expert judgments and field trials. But for practical utility in growers' field there is still a lacuna. In this connection, training programme for the plant pathologists, extension persons as well as for the grower is necessary.

Plant quarantine measures

Exchange of plants/planting material is a potential source of introducing exotic pests. Quarantine measures act as filters against entry of such pests by restricting their introduction and in case introduced, preventing their establishment and further spread. The International Plant Protection Convention (IPPC) of FAO encourages cooperation among various countries and ensures that each country establish a National Plant Protection Organization to discharge such function. In India, the Directorate of Plant Protection, Quarantine and Storage (DPPQS) under the Ministry of Agriculture implements the plant quarantine regulations for bulk consignments and National Bureau of Plant Genetic Resources under Indian council of Agricultural Research (ICAR) is the nodal agency for safe movement of germplasm including transgenics. This work under the Plant Quarantine Regulation of Import in India order 2003 which came into force from 1st January 2004, under the destructive Insect and Pests Act of 1914. Although, the regulations are now in place, there are number of issues related to quarantine of germplasm as it has been drafted more for facilitating bulk imports than for exchange of germplasm. Under this order a pest risk analysis (PRA) has been made mandatory and the various schedule of the order give lists of crops for which a generic PRA is given. A number of cultivated crops (and their germplasm including wild relatives/land races) do not find mention in any of the schemes. Hence, a detailed PRA becomes obligatory for them prior to import. The size of sample/consignment, technique to be used for detection of minute amounts of pest, availability of diagnostic reagents and reference collection of exotic pests, and post entry quarantine testing are important technical issues in quarantine. Over the years, during quarantine processing, the pests intercepted include many like late blight of potato, banana bunchy top, bacterial blight and streak disease of paddy etc that are not known to occur in India, have different races/ biotypes/strains not known to occur in India; are present on new host, are from a country from where they were never reported before or are an entirely new pest species hitherto unreported in science or are reported to be present widely in India. These interceptions, especially of pests not yet reported from India signify the importance of quarantine in preventing the introduction of destructive exotic pests. The need of the hour is to strengthen the agricultural biosecurity system of the country.

New generation fungicides

The process of fungicides discovery has undergone a noteworthy change over the years. After the era of broad spectrum multisite and site specific systemic fungicides, several novel action fungicides of different chemical classes have been developed in the past two decades. These are more eco- friendly and used at a much lower dose rates as compared to the earlier compounds. Most noted among these are the strobilurins (QoIs), derived from *Strobilurus tenacellus*, a wild mushroom. These are analogues to strobilurins –A and have broad range of disease control. Azoxystrobin was the first strobilurin introduced in 1996 and currently nine strobilurins compounds are available. Other important fungicides introduced for the control of diverse diseases in the last decade are Oxazolidinediones (faoxadone), Phenoxyquinolines, (quinoxyfen), Anilinopyrimidines (cyprodinil, pyrimethanil), Valinamides (iprovalicarb, benthiocarb) Mandelamides, (mandipropamid), phenylpyrroles (fenpicloil, fludioxonil), MBIs (carpropamid) Spiroketalamines (spiroxamine), Benzamides (mandipropamid), Cyanoimidazoles (cyazofamid), Thiocarbamates (ethaboxam) and Amdoximes

(cyflufenamid), Phenoxyquinolines (quinoxyfen), Imidazoles (fanmidone), Benzamides (fluopicolide, zoxamide) representing different chemistries and mode of action (Thind, 2012). The majority of these have been developed for use against oomycete pathogens. The main advantages of new generation compounds are ecologically safer and are required to be used at much lower rates than their earlier counterparts. A few of the lately developed fungicides have been registered for use in India and a good number of novel action fungicides are currently under evaluation. Azoxystrobins and fenamidone have been registered for use against grape downy mildew and potato blight. Prominent among those being tested against different diseases are mandipropamid. iprovalicarb, benthivalicarb,, fluopicolide, famoxadone, cyazofamid, pyraclostrobin and kresoxim methyl (Kumar, 2013a).

These recently introduced fungicides to the market represent major advances in technology, potency against target diseases, selectivity, safety and rate reduction. However, they tend to have single site modes of action which makes them potentially affected by target site resistance (Leadbeater, 2012). Thus it is very important to proactively design and implement resistance management strategies and recommendations for new fungicide classes, as well as maintaining existing products. Swift development of resistance to strobilurins is now well documented and these are now categorized under high risk fungicides. Their use has to be regulated and FRAC guidelines adopted so as to sustain their efficacy levels (Kumar and Gupta, 2012).

Spurious pesticides

One of the evils faced by poor farmers of India is the spurious pesticides. It is estimated that spurious pesticides account for about Rs. 1000-1200 Cr. of sales. This results in a net loss to the farmers of crops worth about Rs 6,000 crore (Kumar, 2013a and b). The producers of spurious products manage to escape from the clutches of law, often because of the local authorities either turning a blind eye or being a partner in the crime. Because of this collusion between the criminals and the law enforcing agencies, genuine manufacturing companies have to seek the help of private agencies, to identify and nab the culprits and seek legal course to punish the offenders. This is a very difficult and challenging task, as the local officials from the agriculture and police departments have to be involved to make the entire operation fool proof and to ensure that the offenders do not escape. The manufacturers of spurious pesticides most often target popular and expensive brands from MNCs or leading Indian companies which have better acceptance amongst the farmers. While some of the spurious pesticides contain the active ingredients, mentioned on the label but at a much less percentage than declared on the label, some do not contain any active ingredients. It could be talcum/chalk powder or simply a solvent or kerosene. There are two types of spurious pesticides- those who have 9(4) registration and manufacturing licenses. For them producing products is relatively easier to escape the attention of law makers. The second types are those hard core criminals, often with strong political and official support. If at all, they are caught, they shift their operations to another location in the neighboring state. It is impossible to get them nabbed and punished.

Farmers not only lose their investment on pesticides, but because of spurious fungicides do not control the diseases, the farmers lose their crops also. Here again, the Agricultural department should play their role effectively, by being vigilant, nab the culprits and punish the producers and sellers of spurious pesticides so that this menace is totally eliminated to save farmers.

Adoption / Implementation of IDM

IDM, is multidisciplinary approach seems promising to manage diseases effectively by inclusive amalgamation of cultural, physical, biological and chemical strategies. However, the boon in the knowledge centric array of IDM ironically proves a bane on reaching the knowledge – poor and resource deficient farmers at the implementation stage. Socio economic and educational status of farmers have had a lot of bearing on the adoption/ success of the IDM programme. More worrisome are environmental insensitivities of a majority of farmers, either due to lack of knowledge or desperate economic situations, mainly the rural indebtedness. Unprofessional and unstructured farm mechanism of small land holding makes the socio economic situation of most of the Indian farmers unenviable. Under such situations, the expectation that knowledge intensive IDM should succeed appears far fetched. Under such compelling situations, most of the IDM implementation efforts in the country have been rather sporadic in terms of temporal and spatial. As per current estimates only 5% of the cropped area in the country is under IDM (Mayee, 2006).

Role of plant clinics

Plant health clinics counsel farmers on sick plants the way a health clinic advises humans on their ailments. Diagnosis of the problem is often made on the spot with a prescription given to the farmer. Plant clinics give underprivileged farmers national and international diagnostic expertise. They have enabled scientists to reach more farmers in a timely low –cost way.Preliminary results have shown that the plant health clinics increase incomes and crop harvests and minimize pesticides

abuse. They also lay the foundation for plant health systems. Plant clinics help farmers avoid the futile costs of self-medication, dosing fields with the erroneous pesticides and make sure they use the right one instead or none at all if that works best (Paul, 2012).

Human resource development

The science of plant pathology has a key role in escalating the crop productivity through management of disease. Therefore, disease diagnosis as well as management requires the services of trained plant pathologist who are well acquainted both with basic concept as well as allied fields that is, molecular biology and plant breeding. Of late, new course curricula for PG students have been framed keeping in view the need of the hour. The essential key courses are mycology, plant bacteriology, plant virology, molecular aspects of plant pathogenesis etc. There is dire need to have specialists in these areas. The course on molecular diagnostics, molecular basis of host pathogen interaction, population biology of pathogens using molecular tools and genetic engineering for disease resistance have been added to the course curricula in universities but may not have been much impact since most of the agricultural universities, there is scarcity of scientists to teach basic fundamental courses as well as advance courses. In most of the agricultural universities, mycology and basic bacteriology have taken a back seat. Similarly, knowledge of biotechnological technique is the need of the hour to develop disease resistance genotype and bulk of the teachers do not have adequate exposure to this field. There must be meticulous trainings to teachers at entry level. Most teachers and student of the same university without out side exposure and unaware of many national and international perspectives of agriculture. It would be in the interest of the improvement of agricultural teaching if out of the three degrees, two are from different universities. International exposure of teachers is also indispensable and adequate opportunities to participate in international trainings, professional conferences and other events should be provided. In agricultural universities, many seats in master and doctorate degree are lying vacant due to non availability of students. Steps need to be taken up in promoting agriculture education from the level high school, organizing education fair, encouraging high school student's trip to university and colleges and other means to create general awareness.

Number of fellowships at degree level should be augmented. These steps will help in bridging gap between demand and supply of quality graduates. Further to draw students towards masters and doctoral level education, adequate and large number of fellowships must be available as to lessen the students and parents from financial load. Specialized diploma in plant protection can cater to the need of the farmers at block level. Farmers can also be saved from the clutches of greedy business men in pesticide sale through trained persons. These steps if taken up in right earnest will go in long way in generating the human resource for quality teaching as well as mitigating the sufferings of the farmers.

Perspective

Requirement of disease management in food crops pressed plant pathologist to focus attention on practical plant pathological aspects. It led to lay more emphasis on field oriented research amalgamation of efforts for development of disease resistant varieties. Since 1990s, molecular plant pathology has received attention. Notably, molecular markers have been developed for identification and diagnosis of a number of plant pathogens.

It requires to be strengthened further to garner the benefit of technological advancements. It can be highly useful in understanding the disease of unknown etiology. Molecular plant pathology should be integral part of course curricula for master and doctoral teaching in SAUs. There is a very limited information on impact of climate change on plant diseases. Some focused studies in relation to climate changes needs to be taken up in India. Most effective disease surveillance and expert systems for farmer's advisory are required to be developed.

Forecasting systems for potato late blight, apple scab, powdery mildew of mango, beer and rice blast are now available. But for practical utility in growers' field there is still a lacuna. In this connection, training programme for the plant pathologists, extension persons as well as for the grower is necessary.

Other specific areas of research like disease management using RNA interferences or Post transcriptional gene silencing, nanotechnology and integration of various technologies should draw attention. Plant pathologist is definitely expected to play a grater role in the twenty first century because there is need to meet the international commitment of an open trade under the WTO. There is need to emphasize research on trans boundary movement of plant pathogens since plant pathogens are not only disease causing agents now but also entities of trade significance. National standards of for survey, surveillance and pest free areas (PRA) need to be developed. Hence plant pathologist have a special role for developing PRA, improved and effective quarantine measures developed of national standards is very much required to enhance export of Indian commodities. It needs competent human resources with special trainings. Indian economy is based on agriculture and plant pathology has a special role to meet new challenges for sustainability and advancements of the Indian agriculture.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Characterization of seed potato (*Solanum tuberosum* L.) storage, pre-planting treatment and marketing systems in Ethiopia: The case of West-Arsi Zone

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Potato is a high potential food security crop in Ethiopia due to its high yield potential and nutritional quality tuber, short growing period, and wider adaptability. Arsi administrative province is one of the potential potato growing areas in southern parts of Ethiopia. The potato is grown there as a field crop, and it substantially supplies potatoes to the whole country. Despite the suitability of this area for high quantity and quality potato production in the country, there are several constraints, which drastically affect to the low production and productivity of potato crop by smallholder farmers. The objective of this study was to evaluate the potato seed system, storage, pre-planting treatment practices applied and marketing systems followed by potato producing farmers and to suggest improvement options. In this research, a combination of literature study, expert elicitation, group discussion, field observation, and questionnaire base survey were used. The result of this study showed that a number of factors constraining the system including: unavailability of high quality seed tubers, unavailability of improved varieties, unavailability of improved storage structure, low price of the produce and poor transportation. It is concluded that availability of improved potato varieties, improved storage facilities, use of pesticides and better marketing opportunities are crucial to improve the potato crop system, to alleviate poverty and improve food security of smallholder farmers in the Arsi area in particular and in the country in general.

Key words: Seed potato, pre-planting-treatment, improved storage, seed potato marketing.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is the most consumed food crop world-wide next to wheat and rice (Nicolas et al., 2010; Verzaux et al., 2010; Visser et al., 2009). Although the total per capita consumption is low, potato

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production is rapidly increasing in Africa as well (Fuglie, 2007; Haverkort et al., 2009). This increase in potato production is pronounced from the 1990's since potato is significantly used as a stable food by resource poor farmers and contributes to the livelihood of millions of people worldwide (Verzaux et al., 2010).

In Ethiopia, potato is a high potential food security crop due to its high yield potential per hectare and nutritious tubers. Potato production in Ethiopia is possible on about 70% of the arable land (FAO, 2008; Medhin et al., 2000; Yilma, 1991). Potato is a leading vegetable crop in Ethiopia and smallholder farmers cultivate about 50,000 ha each season (Teriessa, 1997 as cited in Getachew and Mela, 2000). Moreover, in Ethiopia potato production serves as a means to overcome food shortage periods 'hungry months', since it matures before the harvest of other food crops such as cereals (Sanginga et al., 2009). Although the edaphic and climatic conditions are suitable for production of high quality potato in Ethiopia, the national average production is as low as 8 t ha^{-1} (Medhin et al., 2000). This national average yield is very low compared to the potential yield (40 t ha^{-1}) obtained under research conditions (Getachew and Mela, 2000). Lack of quality seed tuber potato (Amede et al., 2006; Hardy et al., 1995; Medhin et al., 2000); high yielding varieties, and storage facilities coupled with poor agronomic practices (Medhin et al., 2000) have been found to contribute to the low yield of potato in Ethiopia. Seed tuber quality refers to the ability of tuber to give a healthy and vigorous plant capable of producing a high yield of good quality within the time limits set by growing season in to which the seed is going to used. The quality of the seed affected by the health of the seed, physiological age and status, size of the seed, purity and genetic quality of the seed (Hirpa et al., 2010). The majority of potato growing smallholder farmers use low yielding and late blight susceptible local varieties due to the limited availability of improved seed potatoes in the country (Getachew and Mela, 2000; Medhin et al., 2000).

At present, chemical treatment and biotechnological techniques are widely applied throughout the world to manage sprouting at a desired level (Farre et al., 2001); which is not a common practice in Ethiopia. Pre-planting dormancy breaking of seed tubers is another important issue in seed potato production (Struik and Wiersema, 1999). In Ethiopia, where potato are produced twice per year, pre-sprouting of the seed tubers prior to planting could lead to higher yields. In addition to the shortage of improved potato varieties, the lack of appropriate seed potato storage contributes to the low production of potato in Ethiopia. For instance, about 30 to 50% yield loss is attributed to the lack of appropriate potato storage and other post-harvest management related problems. (Endale et al., 2008 as cited in Hirpa et al., 2010).

West-Arsi zone is among the main potato growing area in the southern part of the country. The farmers in West-Arsi zone grow potato as a field crop, whereas most of the farmers in other potato growing areas of Ethiopia grow potato as a garden crop mostly for household consumption. Seeds stored in the farm and/or purchased from the farmers of the surroundings and other places are the main sources of planting material in this area. Farmers in West-Arsi area neither practice positive selection nor produce seed tuber on separate plot (Hirpa et al., 2010). Even though West-Arsi zone and the region are suitable for quality potato production, the yields obtained in the area are low (10 t ha^{-1}).

Lack of proper storage systems are among the main factors contributing to the low yield of potato in the region, which is the case at the country level also (Medhin et al., 2002). Furthermore, market price of the product and marketing systems are also problematic. Empirical studies on factors which contribute to low yield of potato crop and profitability of farmers are very few and limited in geographical coverage. West-Arsi zone is among the unaddressed areas. Therefore, there was a strong need to generate quantified data on the storage structures, pre-planting treatment methods, and marketing systems to enhance production and productivity of seed potato, and seed potato producing farmers' profitability.

The purpose of this investigation was therefore, to describe the storage methods, pre-planting treatments and marketing systems practiced in the area, identify the main problems and recommend improvement options. For these purposes the combined efforts of literature review, expert elicitation, formal survey and field observation were used. Based on the obtained data the challenges and opportunities for seed system, storage, pre-planting treatment, and marketing are discussed.

METHODS

The study area

The study was conducted in West Arsi zone, one of the major potatoes growing zones of Oromiya Administrative region, Southern Ethiopia. Three major potato growing districts namely Shashemene, Arsi-Negele and Kofele were purposively selected in the West-Arsi zone, since these districts are potential potato producing areas and can considerably contribute to the supply of potatoes to the country. The area also known by growing a huge variety of potatoes mainly of Agazer, Nech abeba, Jalene and Gudane. These districts ranked second, third and fourth in potato production potential from the twelve districts in the zone. Moreover, the area is research unaddressed and affected by different problems including diseases, unavailability of improved varieties and lack of advanced production technologies. This was identified during ground truth assessment done before defining this research. Furthermore, different Kebeles/villages were considered from each of the three districts. The Kebeles was also selected based on their potential of potato production. The three districts considered in this study are 230, 250 and 275.1 km (Arsi-Negele, Shashemene and Kofele respectively) southeast of the capital city, Addis Ababa.

Data collection techniques

The data was collected in five different stages. Literature review,

expert elicitation, rapid appraisal, formal survey and field observations were carried out to solicit the appropriate data.

Literature review

To describe the seed potato system, secondary data was collected. Zonal agricultural and rural development office annual reports were reviewed and information on total arable land, total annual production of vegetable crops and the contributions of potato crop for the total yield were obtained. The literature review was useful to obtain general understanding of the subject matter related to the objective of the study and the importance level of the crop in the area ahead of field work. Moreover, reviewing the secondary information helped to understand the main problems or issues and gaps that need to be emphasised and addressed during the study.

Expert elicitation

Following the literature review, an interview was made with different professionals from agricultural and rural development office, and one non-governmental organization. Information on pre-planting seed treatments, storage methods used and marketing systems were obtained from the interviews. The information was obtained through thorough discussion with agricultural and rural development office heads and experts of the three districts (Shashemene, Arsi-Negele and Kofele).

Rapid appraisal

The rapid appraisal survey was executed to obtain specific qualitative information. During rapid appraisal survey stage, the main problems associated with seed potato production practices were also discussed. This stage, allowed us to make a free discussion on issues related with the study objectives. Thus information was also used to strengthen and develop the final questionnaire.

Field observation

Field observation were conducted in some potato production farmers' plots and in improved variety demonstration plots planted by Kofele district agricultural office.

Quantitative survey

After rapid appraisal survey, quantitative survey was executed using the structured questionnaire in all the three districts. Quantifications of these important parameters used to confirm the qualitative information gathered during the qualitative data collection stage, to assess issues untouched during qualitative survey and to present the findings with empirical evidences. Structured questionnaire was designed by incorporating the feedbacks from rapid appraisal survey on the pre-designed semi-structured questionnaire. The questionnaire was pre-tested and based on the pre-test input and then the final questionnaire was designed. A total of 91 respondents (31, 30 and 30 from Shashemene, Arsi-Negele and Kofele, respectively) were selected and the survey was executed.

Data management

Relevant information obtained from all parts of the data collection was summarized using tables, pictures and graphs. To analyse and summarize the quantitative data obtained from quantitative survey, the questionnaire was tabulated, coded, and excel and descriptive statistics using SPSS software was employed.

RESULTS

Seed potato storage practices and methods

Storing potato either for ware or seed is a common practice in the study area. Majority of the sampled farmers have experience of storing potato (Table 1). Storing potato allows the farmers either to use tubers of their own harvest as a seed source, to postpone sales to get better market price, and for household consumption in the later season. Potato farmers in the study area used different traditional storage methods to store seed potatoes (Table 1).

These storage facilities do not allow the farmer to store seed potatoes for long periods. Using these traditional storage methods, the farmers store seed potatoes on average for three and half months without tuber deterioration. Leaving potatoes unharvested (storage in the field) encounters different challenges such as untimely rainfall that hasten tuber rotting and tuber moth that cause considerable yield loss. None of the sampled farmers used improved-diffused light storage. Ninety percent of the farmers stored seed potato in bulk. Bulk store cause physical damage to the tubers, affecting the sprouting capacity and market acceptance of the tubers. Furthermore, farmers did not practice any kind of storage facilities which may keep the seed tubers for longer periods without deterioration. Sacks are the main packages used to put-in potato after harvest for temporary storage and for transportation. Sacks do not protect the tubers from physical damage caused during transportations. This can result in secondary physiological and pathological losses. After transporting to home, farmers' keep the tuber outdoor covered with canvas temporarily then bring to storage structures (Figure 1).

Eighty-nine percent of the sampled farmers identified unavailability of improved storage facility as a main problem (Figure 2) related to keeping potato seed for long period of time. The available traditional storage methods cannot keep seed tuber until the next planting season free of damage. The reasons of using traditional storage methods were their availability, their low cost, and the unavailability of improved storage facilities. Forty-seven percent of the farmers store potato tuber in their house which is inconvenient because of the wide space occupied by the tubers. Some farmers used 'gotera' (local storage structure).

Unavailability of improved storage facilities forced farmers to sell potato product immediately after harvesting at low price and buy seed during planting at very high cost. They also explained that if improved

Table 1. Farmers experience of storing seed potato and storage methods used in the study area (% of farmers).

Variables	Number	Percent
Farmers storing seed potatoes	57	63
Storage method		
In the soil/delayed harvesting	9	16
Dark space in the house	31	54
'Gotera'	9	16
Spread outside the house	8	14

Figure 1. Farmers practice of temporary store in the outdoor.

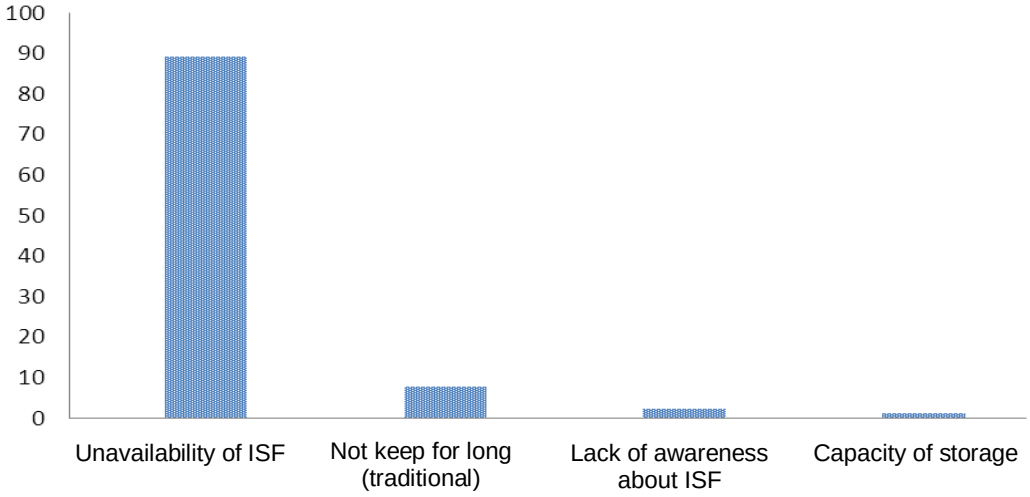

Figure 2. Main problems related to seed potato storage (% of respondents). Note: ISF - improved storage facility.

storages were available the cost of production input could not be a problem, since the storage would allow them to sell the tuber with better market price later in the season.

Pre-planting treatment methods

Ninety-five percent of the sampled farmers practice pre-planting treatment to advance sprouting. None of them indicated the use of pre-planting treatment methods for other purposes like soil-borne diseases protection. Farmers used traditional sprouting techniques prior to planting to stimulate sprouting. Covering the seed potato tuber with straw was the most popular method practiced by farmers. Putting the tuber on the sun and combination of the aforementioned methods were also practiced

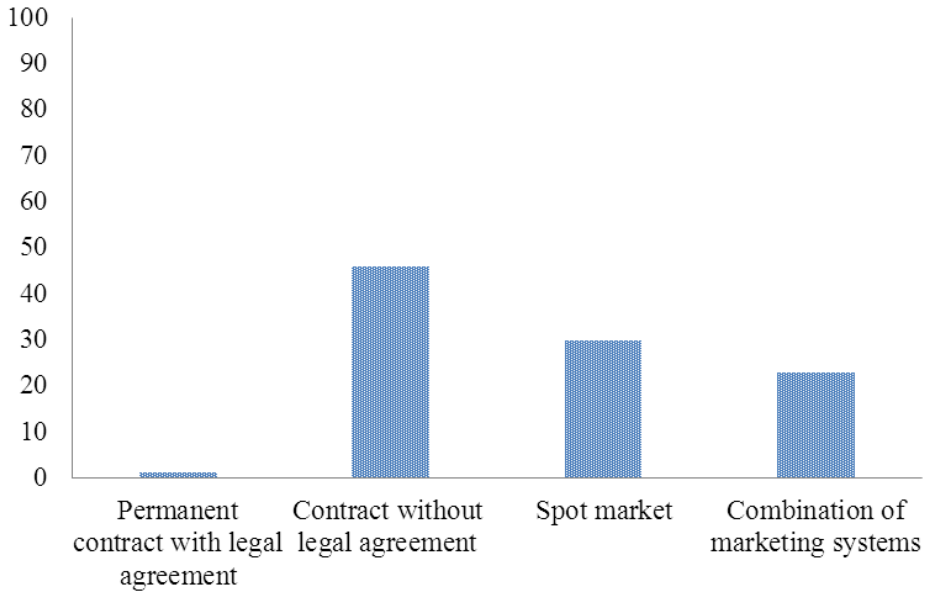

Figure 3. Seed potato marketing systems (% of respondents).

frequently. In the combined case they put the tubers first on the sun for some days and then cover them with straw. Those farmers, who did not found practicing any techniques to enhance tuber sprouting; mentioned lack of awareness about the importance of the practice as the main reason for not applying pre-planting treatment followed by labour required for the practice.

Seed potato marketing systems

Potato is a main food and cash crop in the study area. Of the sample farmers 87% of them had an experience of selling potato for different parties. The potential sources to sell potato are traders and/or farmers/consumers. Farmers produce potato primarily for marketing followed by household consumption. This also contributes a lot for potato seed system, since the farmer exchange seed potato tubers within a district and/or across districts. There is no difference in production management between market oriented and home consumption. Farmers did not know exactly the fraction they sell for seed. Farmers explained that the traders may sell the tuber as seed in other places. Farmers know whether it is used for seed when they sell to neighbour and to other district farmers.

Some farmers also reported that a number of farmers from other parts of the country had taken seed potato from this area. This shows that the local seed exchange system has been delivering important services to farmers producing potato in and outside of the study area. Moreover, farmers are also getting premium price when they sell the potato tuber as seed than as ware potato. However, selling tubers as a seed faces different problems such as low market demand, unavailability of improved storage facilities, inaccessibility of the area and high cost of transportation.

Different marketing systems practiced to sell seed in the study area. Majority of the farmers make contract without legal agreement mediated by broker during potato harvest contributing 46%. Spot market and selling for neighbour and other districts farmer are the main marketing system for seed potatoes although spot market used frequently accounting 30%. Of the farmers who sold potato 23% used a combination of marketing systems, whereas 1% of the sample farmers used permanent legal contract system (Figure 3). Combined use of two different marketing systems helped the farmers. The part sold during harvest helped the farmers to cover their immediate cash need, whereas the part sold in the later season helped them to get high price, since the price get better during planting or in the latter season.

Market sources

The surveyed farmers sold seed potato to different groups of clients. Traders who bring the potato tuber to the different parts in the country were the most dominant market source constituting about 49% of the total market opportunities. Farmer to consumers was the second market sources contributing 43% of the total market opportunities, whereas direct farmer to farmer exchange covers about 8% of the market sources.

In the studied districts farmer sell potato in different periods. About 70% of the sample famers sold potato produce immediately after harvest, whereas only 17 and 13% of them sell potato later when the market price

become high and during planting, respectively. This is largely related with unavailability of improved storage facilities and the low keeping ability of the available traditional storage systems and, this reduces the profit that, the farmers likely to get from potato farming and the amount sold as seed. Furthermore this restricts the farmers to adopt low rate application of production inputs, this is because they sell the produce with low price and expect to spend more to get the production inputs. Farmers preferred to sell potato at farm gate than to bring to market. Farmer reported the price they could fetch through the informal contract was lower than the price at spot market, but the cost of the transport forced them to sell in the farm gate. On the other-hand farmers are less involved in price setting thus the broker is the dominant party who set the price of potato.

Farmers explained that the brokers set prices in a way that benefits themselves. For instance, if a trader is willing to pay ETB 140 per 0.1 Mg, the brokers tell the farmers the price per 0.1 Mg is ETB 120 and takes the difference (ETB 20 per 0.1 Mg). Despite this huge exploitation more than 50% of the sample farmers need the brokers because it is difficult for them to market without the intervention of brokers. This shows the complexity of the problem the farmers are facing in relation to potato marketing. Seed potato marketing was affected by different factors among which low demand for seed potato is the main one contributing more that 90% of the problems in this regards. Storage, low price of the product and means of transportation were among the other factors that affected seed potato marketing. The assistance from agricultural and rural development office on seed system, including production and marketing is insignificant.

DISCUSSION

Seed potato storage

The results of this study showed that from the farmers who stored seed potatoes none of them used improved storage facilities. The entire dependency of farmers on traditional storage system might be due to the lack of improved storage system like diffused light storage (DLS). DLS is a cheap storage technology which can substitute alternative temperature-controlled storage system (Rubatzky and Yamaguchi, 1997 as cited in Mulatu et al., 2005). Agajie et al. (2007) reported the use of DLS by potato farmers in the Western part of Ethiopia, and its considerable advantage over the traditional storage system. The advantage DLS over traditional storage system explained by the long time keeping ability of this storage system. Moreover, tubers stored in DLS system produce robust and short sprout; this also makes the transportation easy and reduce breaking of sprout during market to home as well as to field transportations and the tuber stored in DLS resulted in production of more number of stem per plant. Whilst the tuber stored in the traditional storage system produces long etiolated sprout which is susceptible to breakage during transportation and result in production of less number of tillers in the field. Lack of awareness about this low cost and better keeping ability storage system might hinder farmers not to use it (Agajie et al., 2007; Mulatu et al., 2005). The results of the present study showed that, farmers in the studied area stored potato for three and half months on average using traditional storage systems. Similarly, Agajie et al. (2007) reported four months storing ability of local storage systems. In addition to the short time storing ability of the local storage systems, the tubers stored in these storage results with less number of stems per plant and the plant is also not vigour. The dependency of farmers on traditional storage system explained by absent of improved storage systems and lack of knowledge on the importance and construction of this storage system (that is, DLS), otherwise the farmers explained the low keeping ability and capacity of the traditional storage they are using currently. This confirms the importance of the introduction of improved storage systems in the area.

However, potato storage had tremendous advantage for potato farmers in the studied area. Storage creates opportunity to look for high market price in the later season as well as help farmers to keep potato tuber as a seed and to have their own seed sources for the subsequent season. The substantial contributions of farmers own harvest in the potato seed source (30% the current study) increases the value of storage for potato producers in the area. Some previous studies (Gildemacher et al.,2009) 50% in East Africa and (Mulatu et al., 2005) 45% in the Eastern Ethiopia were reported the contribution of farmers own harvest in potatoes seed source, which shows the importance of storage in this regard. The local storage facilities cover 100% of the current storage system in the studied area. Moreover, these traditional storages are not able to store for long without tuber deterioration, low holding capacity, reduce the farmers housing safety for those who store in the house. Based on the results of the present study several suggestions can be made to overcome storage related problems in seed potato system in the area. Introduction and dissemination of improved storage structures such as DLS from research addressed areas. This helps the farmers to overcome storage related problems, since DLS can store seed potatoes for long period (six-to-eight months) without deterioration (Agajie et al., 2007; Jalleta, 1976 as cited in Mulatu et al., 2005), which is longer storage period as compared with that of traditional systems which only found to store for about three to four months on average. This could be supported with training to increase farmers' awareness about the system and hasten adoption rate of the technology. Moreover, in store potato management is not practiced in the studied

area. This shows the lack of knowledge in this regard and calls for more emphasis to solve this problem. This is because the pre-storage state of the tuber takes immense share in determining the length of the shelf life of the tuber without deterioration (Pringle et al., 2009). Farmers also found to store potato temporarily in the outdoor. This might expose the tuber to external environment which result in the tuber quality reduction by causing tuber condensation (Pringle et al., 2009). Exposing the already sprouting seed tuber also found causing negative effect by fastening the physiological ageing (Struik and Wiersema, 1999). Moreover, occurrences of rain fall when the potato is in the outdoor cause deterioration. This kind of storage also increase the opportunity for tuber physical damage since it involves moving of tuber later to the permanent store as well as animals may reach the tuber stored in the outdoor. To solve storage related problems a cooperated effort of the professionals in this field and the extension workers in the area as well as the agricultural officers are crucial. The already farmers available traditional storage systems can be improved by investing scientific knowledge. According to Rhoades (1989, as cited in Mulatu et al., 2005) DLS developed by refining the already farmer available storage system. Improving the already farmer available storage and letting them to use it also hasten the adoption of the system by farmer since it is already on their hand and they might have indigenous knowledge and skill on the construction and use. In addition, market facilitation by the concerned body should be done to let the farmer to get market with premium price during harvest, and also make the seed potato accessible for farmers during planting; this may be done by developing public seed storage in the farmers' vicinity.

Seed potato pre-planting management

From the farmers who practiced pre-planting treatment on seed potato, all of them only did for sprout enhancement. The absence of treatment practices for other advantage like diseases management were attributed to lack of awareness of the farmers about the advantage of applying pre-planting treatment. Uses of chemicals like ethylene chlorohydrin, thiourea, and potassium thiocyanate (5, 6, and 12) to advance sprouting, keeping uniformity of sprout and to get maximum stand of potatoes at field is reported by Rappaport et al. (1957). Moreover, the pre-planting treatments applied by the farmers were entirely traditional and based on their own experience. Majority of the farmers attempted to increase temperature in the environment of the tuber for some time before planting. Arsenault and Christie (2004) and Wiltshire and Cobb (1996) suggested exposing the tuber to warmer condition prior to planting to motivate sprouting, early ground cover and to get vigour crop stand. Only a small number of farmers were found not applying treatment to advance sprouting. These farmers might not be interested to invest more time and labour on sprout enhancement so that cost of production would be low. This situation calls for due consideration on how the awareness of farmers towards application of pre-planting treatment can be increased and how the traditional pre-planting treatments can be improved. Different options can be suggested to solve the pre-planting treatment problems. Training can be done to increase farmers' awareness towards the importance of pre-planting treatment application. In-depth study can be made on the already available traditional treatment methods to understand the weakness and refine by incorporating scientific knowledge. Furthermore, investigation for modern treatment practice and treatment inputs can be done.

Seed potato marketing

As the results of this study showed seed potato marketing delivers paramount services to potato producers in the study area. Most (87%) of the farmers in the study areas sold potatoes. The amount which is exactly sold as a seed is not notable by farmers. This is because; the buyer may use it as a seed or as a ware. The farmers only know whether it used for seed if only the neighbour farmers buy from them as a seed. As per their explanation potato contributes a lot in the income generation. However, the present study identified a number of problem related to seed potato marketing in the studied area. Low market demand for potato tuber as a seed and lower price as compared to production cost were among the main factors. Similarly, Agajie et al. (2007) reported lack of buyer and low price as popping problems in relation to seed potato marketing in Jeldu and Degem districts in Ethiopia. The difference between the result of the present study and that of Agajie et al. (2007) is that, the farmers in the Jeldu and Degem districts were already distinguished the seed and ware potato and they might look only for seed potato market, whereas in the case the present study area the farmers immediately sell the tuber as a ware due to fear of market unavailability for seed potato. Seed potato marketing problems also related with lack of appropriate storage facilities. This is because availability of better storage allows the farmers to sell seed potato tuber during planting when the market price become high than during harvest. According to Mulatu et al. (2005) unavailability of proper potato seed storage forces the farmer to sell immediately during harvest with low price, whereas availability of proper storage facilities allow farmers to sell their potato tuber as a seed during planting or in the later season with higher price compared to the immediate sell.
In the other ways market played an important role as a seed source for the potato producers in the study area contributing 60% of the seed sources. This result is

supported by the finding of Agajie et al. (2007) which revealed the significant contribution of market as a seed source (56%) in Banja district of Ethiopia. But, the sample potato producers in the study are explained the low quality of the seed tuber which came from market. According to Hirpa et al. (2010) and Mulatu et al. (2005) the seeds which came from market were not pure, healthy and had inappropriate physiological age. Since the livelihood of the farmers and purchase of farm inputs for potato production in the studied area are largely dependent on the income from potato, it is plausible to look for different seed potato market improvement options. Research on priorities for potato research in developing countries has found that, improved potato marketing system is the most important post-harvest activity in potato system (Fuglie, 2007). It is also one of high ranked priority needs of potato producing farmers in developing countries (CIP, 2004 as cited in Fuglie, 2007). According to Fuglie (2007) poor storage condition is one of the causes for market fluctuation. The seed storage structure and availability can be improved. This is in line with the findings of Guenthner (2006) in which storage development and management to improve the seed tuber production and marketing scheme in Ethiopia was recommended. Furthermore, networking the farmer with market information can be done by the concerned body so as to reduce the domination of the broker over farmers during price setting. Fuglie (2007) found lack of information as a cause for price fluctuation. Moreover, further research effort into evaluation of potential seed potato marketing strategies and the development of sustainable seed potato marketing system is needed.

Conclusion

Potato producing farmers in the studied area were dependent on the traditional methods of seed potato storage, pre-planting treatment and also inefficient marketing systems. In the area, the problems in relation to seed potato system are complex and wide ranging such as: poor market demand, low price, lack of improved storage technologies and absence of improved pre- plant treatment techniques. As far as the improvement of the system is concerned the transportation, storage, marketing and treatment methods should be improved.

RECOMMENDATIONS

Unavailability of improved varieties was identified as a major problem. This calls for the supply of improved varieties which fit with the agro-ecology with their improved production packages. All the stakeholders need to take responsibilities to address this.

Unavailability of improved storage facilities was also identified to be a major problem. This is because the improved storage facilities like DLS are not disseminated to the study area, which is already in use in other major potato producing areas of the country. This calls for cooperated efforts of stakeholders to introduce and disseminate improved technologies to the area.

Low market demand and low price of the produce was reported as a problem in the study area. Creation of sustainable market opportunities through formation of seed potato production and marketing cooperation, improving the transportation system and road, and creation of bilateral agreement between farmer and seed agents or merchants are desirable to solve market related problems.

Entire dependence of farmers on traditional pre-planting treatment and un-uniform use of the treatments are reported. This is because farmers' practices were not supported with training. This calls for strengthening the farmers practices through more scientific knowledge supported training.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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