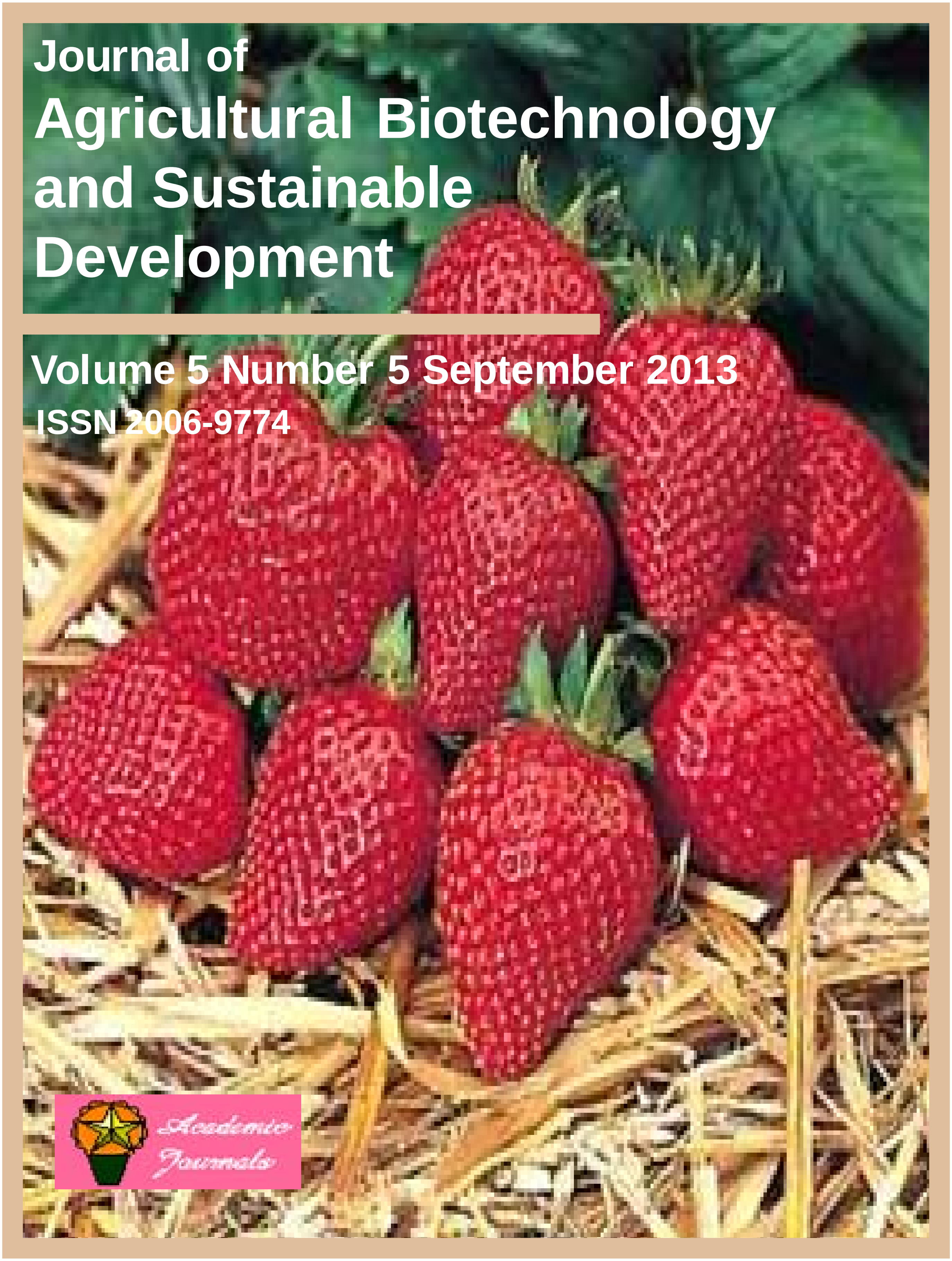

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Pitout JDD, Church DL, Gregson DB, Chow BL, McCracken M, Mulvey M, Laupland KB (2007). Molecular epidemiology of CTXM-producing Escherichia coli in the Calgary Health Region: emergence of CTX-M-15-producing isolates. Antimicrob. Agents Chemother. 51: 1281-1286.

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Journal of Agricultural Biotechnology and Sustainable Development

Full Length Research Paper

Determination of some agronomic characters in different age groups of traditional rice cultivars in Sri Lanka under fertilized and non-fertilized conditions

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Yields of traditional rice cultivars are typically low. The objective of this study was to understand the yield and agronomically important phenotypic traits of some traditional rice cultivars with different days to maturity at fertilized conditions. A field experiment was done at Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka during *Maha* 2011 to 2012 and *Yala* seasons in 2012. The recommended fertilizer dose for improved rice cultivars was applied for the study. Effect of fertilizer on agronomic characters namely plant height (cm), number of tillers/plant and number of leaves/plant were measured during the experiment. Grain yield (g/plant) and harvest index were calculated at the end of the experiment. All the evaluated parameters were significantly higher at the fertilized conditions than those of at non fertilized conditions except the plant height in 161 to 165 days to maturity age group and number of leaves/plant in 110 to 115 days to maturity age group. At fertilized conditions the lowest significant plant height (97.5 cm) was recorded in the 161 to 165 age group while 151 to 155 age group recorded the significantly highest plant height (138.4 cm). The number of tillers/plant ranged from 6.0 to 9.8 while the highest significant number of tillers/plant (9.8) was recorded in 110 to 115 age group. However the highest grain yield/ plant (23.0 g) was recorded in the shortest days to maturity age group (110-115). Supporting this, the highest average yield/plant (10.1 g) at non fertilized conditions was also recorded in early maturing cultivars belong to 110 to 115 days to maturity age group.

Key words: Agronomic characters, traditional rice, fertilizer effect, days to maturity.

INTRODUCTION

The rice plant usually takes 3 to 6 months from germination to maturity, depending on the variety and the environment under which it is grown. The optimal growth duration for maximum yield of inbred *Indica* varieties in the tropics is about 120 days (Tanaka et al., 1976). There was a linear increase in total biomass as growth duration increased from 95 to 135 days whereas maximum grain yield of about 8 to 9 t/ha was constant in varieties of 110 to 130 days (Akita, 1989). Varieties of shorter growth duration usually give lower yields at typical hill spacing in transplanted rice due to insufficient vegetative growth for maximum yield levels (Yoshida, 1976).

Pandey et al. (2012) reported that late maturing and taller rice genotypes had high spikelet fertility contributing towards higher grain yield. The real situation of individual rice cultivars in traditional rice gene pool in Sri Lanka is no informative. Discovering factors such as yield potential, response of traditional rice cultivars to fertilizer,

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behavior of yield potential of the rice cultivars at fertilized condition must be depleted in systematic way in the process of utilization of none utilized or under-utilized rice cultivars for the improvement of rice cultivars by interrogation of favorable trait from traditional cultivars in to the modern rice cultivars.

Traditional rice cultivars in Sri Lanka were evaluated for some abiotic stress tolerance in systematic way (Ranawake et al., 2010, 2011; Rodrigo et al., 2012; Weragodavidana et al., 2012). The selected abiotic stress tolerance rice cultivars have a potential of direct introduction in to farmer fields (Djilianov et al., 2005; Xiang et al., 2007) or utilization of them in the breeding programs (Djilianov et al., 2005; Xiang et al., 2007; Ashfaq et al., 2012) of development of abiotic stress tolerance rice cultivars. In such a process, poor yield potential of traditional rice cultivars is a great problem to be overcome (Jennings, 1964; Saito et al., 2006; Amarasinghe et al., 2013). Some of the Sri Lankan traditional rice cultivars have also been evaluated in different fertilizer levels in Sri Lanka (Amarasinghe et al., 2012; Dharmasena 2012). Taking in to consideration of crop nutrition, nitrogen plays an important role in crop life. It is one of the most important nutrients needed in large quantities for the plant growth and development (Arif et al., 2010). The best level of fertilizer applications for the maximum benefit is among the most important strategies in rice crop management (Arif et al., 2010).

Plant height, number of tillers per plant, panicle length, flag leaf area, primary branches per panicle, days to heading, and days to maturity are more effective as compared to other traits in boosting yield performance of rice (Ashfaq et al., 2012; Osman et al., 2012). Among these characters plant height and days to maturity showed the highest variations among the genotypes in rice (Ashfaq et al., 2012). The degree of correlation among the characters is an important factor especially in economic and complex characters such as yield (Akinwale et al., 2011; Khan et al., 2009). Akinwale et al. (2011); and Panday et al. (2012) observed a positive and non significant correlation in between grain yield and days to maturity. Harvest index and days to maturity have also exhibited very high positive direct effect on grain yield (Panday et al., 2012).

In the present study rice cultivars with different days to maturity were analyzed to understand the fertilizer response of them at the field conditions. In the same time some of the agronomic characters were evaluated to see the contribution of them to yield increment under fertilized conditions.

METHODOLOGY

Fifty traditional rice cultivars (Table 1) were geminated and planted in nursery beds. Ten day old seedlings were transplanted in the field at Faculty of Agriculture, University of Ruhuna in rows with 15 × 20 cm spacing. Experiment was conducted as a randomized complete block design with four replicates. Each replicate consisted 3 rows of 20 rice plants. The recommended fertilizer dosage for modern rice cultivars (Basal Dressing: Urea 50 Kg/ha, TSP 62.5 Kg/ha, MOP 50 Kg/ha and Top Dressing: Urea 37.5 Kg/ha – 2 Weeks after planting and 8 Weeks after planting) was applied in recommended intervals. Control experiment was carried out without any fertilizer applications.

Plant height (cm) of individual rice cultivars was measured at reproductive stage in the middle row plants of the three-row-grown rice cultivars. Here, plant height was considered as the length in cm from the plant base to the tip of the highest leaf (or panicle, whichever was longer) (Ashfaq et al., 2012). Number of tillers/plant was counted at the age of 12 weeks of rice cultivars. Number of leaves/plant was counted at the vegetative stage before flowering, after second top dressing was applied in to the field. Grain yield (g/plant) was measured in individual rice cultivar after harvesting and removing unfilled grains. Harvest index was calculated according to Li et al. (2012) as follows:

$$\text{Harvest index } \alpha = \frac{\text{Grain yield (g)/plant}}{\text{Total biomass (g)/plant}}$$

Fifty traditional rice cultivars were categorized into seven age groups according to days to maturity; 110 to 115, 116 to 120, 121 to 125, 126 to 130, 131 to 135,151 to 155, 161 to 165. Days to maturity was decided according to the characterization catalogue on rice germplasm (Plant Genetic Resource Center, 1999).Data were statistically analyzed by ANOVA and mean separation were adjusted by DMRT using SAS statistical software (SAS Institute Inc., 2000)

RESULTS AND DISCUSSION

Harvest Index, yield/plant, and number of tillers/plant in traditional rice cultivars were significantly increased by inorganic fertilizers in all the age groups (Table 2). Plant height was significantly reduced by recommended fertilizers only in the longest age group. Only in the shortest age group number of leaves was significantly reduced by the recommended fertilizers. The days to maturity of the selected traditional rice cultivars spanned from 110 to 165. Plant height, number of tillers/plant, number of leaves/plant, average yield/plant and harvest index ranged from 97.5 to 138.4 cm, 6.0 to 9.8, 11.3 to 15.5, 5.0 to 23.0 g, 0.11 to 0.33 respectively, at fertilized conditions (Table 2) while at non fertilized conditions those parameters ranged from 106.5 to 133.3 cm, 3.9 to 5.3, 7.1 to 13.7, 2.1 to 10.1 g, 0.09 to 0.32. The significant lowest average plant height (97.5 cm) was recorded in the 161 to 165 days to maturity age group and the highest significant average plant height (138.4 cm) was recorded in the 151 to 155 days to maturity age group at the fertilized conditions. At non-fertilized conditions, the lowest significant average plant height (106.5 cm) was recorded in the 110 to 115 days to maturity age group and the highest significant average plant height (133.3 cm) was recorded in the 151 to 155 days to maturity age group.

According to Panday et al. (2012) late maturing and taller rice genotypes had higher spikelet fertility contributing towards the higher grain yield. Yoshida

Table 1. PGRC accession numbers and names of fifty traditional rice cultivars.

PGRC Acc No	Name	Days to maturity	PGRC Acc No	Name	Days to maturity
3423	*Giress*	122	3658	*Ingrisi wee*	124
3427	*Naudu wee*	127	3659	*Kotathavalu*	119
3434	*Kokuvellai*	125	3660	*Suduru*	119
3435	*Matara wee*	124	3661	*Polayal*	124
3438	*Murunga wee*	117	3664	*Tissa wee*	124
3440	*Kaharamana*	127	3665	*Sudu Karayal*	124
3445	*Yakada wee*	119	3666	*Podisayam*	125
3447	*Karabewa*	123	3668	*Ranruwan*	113
3451	*Halabewa*	123	3669	*Rajes*	119
3463	*Karayal*	115	3670	*Madoluwa*	127
3469	*Sudu wee*	121	3671	*Suduru Samba*	125
3477	*Sudu Goda wee*	110	3673	*Kaluhandiran*	126
3479	*Kiri Naran*	134	3674	*Kirikara*	119
3480	*Karayal*	122	3675	*Kotathavalu*	118
3482	*Akuramboda*	128	3676	*Dena wee*	117
3486	*Puwakmalata Samba*	163	3677	*Herath Banda*	117
3487	*Palasithari 601*	123	3678	*Hondarawala*	125
3489	*Murungakayan 3*	125	3679	*Kottakaram*	126
3490	*Murungakayan 101*	128	3681	*Dandumara*	127
3496	*Bala Ma wee*	122	3686	*Karayal*	124
3638	*Lumbini*	118	3687	*Dewaredderi*	125
3639	*Polayal*	111	3688	*Handiran*	118
3641	*Heendik wee*	128	3691	*Gunaratna*	155
3642	*Kahata Samba*	118	3659	*Kotathavalu*	119
3653	*Kalu Karayal*	125	3660	*Suduru*	119
3654	*Pokuru Samba*	125	3661	*Polayal*	124
3655	*Rata wee*	118	3664	*Tissa wee*	124

Table 2. Agronomic characters of traditional rice cultivars at non-fertilized conditions and at fertilized conditions.

Days to maturity	Plant height (cm)		Number of tillers		Number of leaves		Yield (g) /plant)		Harvest Index	
	No F.	RD	No F.	RD	No F.	RD	No F.	RD	No F.	RD
110-115	106.5^{b}	123.1^{a}	5.0^{b}	9.8^{a}	12.6^{a}	11.3^{b}	10.1^{b}	23.0c^{a}	0.24^{b}	0.3^{a}
116-120	115.3^{b}	122.4^{a}	4.9^{b}	6.0^{a}	13.2^{a}	13.2^{a}	7.1^{b}	12.5^{a}	0.27^{b}	0.33^{a}
121-125	121.4^{b}	128.0^{a}	5.3^{b}	6.8^{a}	11.4^{b}	13.0^{a}	9.6^{b}	14.1^{a}	0.28^{b}	0.33^{a}
126-130	114.0^{b}	118.7^{a}	4.6^{b}	6.3^{a}	10.8^{b}	12.6^{a}	9.7^{b}	13.7^{a}	0.32^{b}	0.35^{a}
131-135	126.3^{a}	125.9^{a}	4.5^{b}	7.2^{a}	10.8^{b}	15.5^{a}	7.4^{b}	13.4^{a}	0.28^{b}	0.32^{a}
151-155	133.3^{b}	138.4^{a}	5.3^{b}	6.3^{a}	13.7^{a}	13.8^{a}	9.1^{b}	11.3^{a}	0.29^{b}	0.3^{a}
161-165	119.0^{a}	97.5^{b}	3.9^{b}	7.7^{a}	7.1^{b}	11.8^{a}	2.1^{b}	5.0^{a}	0.09^{b}	0.11^{a}

Means with the same letter are not differ significantly; No F= No fertilizer; RD = Recommended fertilizer.

(1976) has revealed that varieties of shorter growth duration usually give lower yields at typical hill spacing in transplanted rice due to insufficient vegetative growth for maximum yield levels. However the earliest maturity group has responded in different way in the present study; the highest yield has been reported in the earliest maturing group (Table 2). Peng et al. (1994) has reported that rice cultivars those take 110 to 120 days to maturity were considered as medium growth duration varieties those can produce higher total yield. Finding of Peng et al. (1994) is aligned with the findings of the present study (Table 2).

Moreover, the lowest harvest index was recorded in the longest age group (Table 2) at fertilized (0.11) and at non fertilized (0.09) conditions providing evidence on the effect of other factors rather than days to maturity on the yield determination of the studied rice cultivars. Under fertilized conditions the average number of tillers/plant ranged from 6.0 to 9.8 in the analyzed traditional rice cultivars. The highest average number of leaves/plant (15.5) was recorded in the 131-135 age group (Table 2). The highest grain yield/ plant (23.0 g) was recorded in the 110-115 age group, which included the cultivars with shortest days to maturity while the lowest grain yield/plant (5.0 g) was recorded in the 161-165 age group, which consisted of the cultivars with comparatively longer days to maturity. Further, the highest number of tillers/plant (9.8) was also recorded in the early maturing age group (110-115 days to maturity) while the lowest average number of tillers/plant (6.0) was recorded in 116-120 days to maturity age group (Table 2).

Harvest indices (HI) ranged from 0.11 to 0.35 in the cultivars used for the present study. This value in modern rice cultivars is more than 0.4 (Li et al., 2012) while it is varied from 0.4 to 0.6 in modern rice cultivars in Sri Lanka (De Costa et al., 2003; Wickramasinghe, 2011). The highest value of HI (0.35) in the present study was found in the 126-130 days to maturity age group. Panday et al. (2012) concluded that the harvest index, days to maturity and the effective tillers/plant as the major contributors for rice yield. So the rice cultivars with higher magnitude of these traits could be favorable for better yield in farmer field.

Under non fertilized conditions the average number of tillers/plant ranged from 3.9 to 5.3. The highest number of tillers/plant (5.3) was recorded in age groups; 121 to 125 and 151 to 155 while the lowest number of tillers/plant (3.9) was recorded in late maturing age group; 161 to 165 (Table 2). The highest number of leaves/plant (13.7) was recorded in the same 151 to 155 days to maturity age group which recorded the highest number of tillers/plant (Table 2). The highest grain yield/ plant (10.1 g) was recorded in the 110 to 115 early maturing age group, while the lowest grain yield/plant (2.1g) was recorded in the longest age group; 161 to 165. Harvest index (HI) ranged from 0.09 to 0.32 in the cultivars at non fertilized conditions. The HI values of the age groups with days to maturity 126 to 130 (0.35) was closer to the lower limit of the reference HI values of Sri Lankan modern rice cultivars (0.4 to 0.6) according to De Costa et al. (2003) and Wickramasinghe (2011). However the HI of age groups of 110 to 115 (0.3), 116 to 120 (0.33), 121 to 125 (0.33), 131 to 135 (0.32), 151 to 155 (0.3) and 161 to 165 (0.11) recorded the lower values than that of in modern rice cultivars in Sri Lanka.

Conclusion

All the evaluated parameters were significantly differed with the fertilized conditions than those of at non fertilized conditions except the plant height in 161 to 165 days to maturity age group and number of leaves in 116 to 120 days to maturity age group. The highest significant grain yield/plant can be obtained by planting cultivars in 110 to 115 days to maturity age group at fertilized conditions and at non-fertilized conditions as well. However for the highest harvest index, cultivars in relatively short days to maturity age group (126 to 130) are more suitable.

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Full Length Research Paper

Crop-machinery management system for field operations and farm machinery selection

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The main objective of this study is to develop a computer system for farm management and selection of required farm machinery to perform field operations in time for crops grown in rotations. Excel and Visual basic software were used to develop the program. The input data included 4 crops (sorghum, sesame, sunflower and cotton), 3 field operations (seedbed preparation, seeding, and weeding operations) and 3 farming systems (zero-tillage, conventional, and heavy machines farming systems). In addition, tractor and 6 implements (wide level disk, disk harrow, chisel plow, row crop planter, inter-row cultivator and sprayer) were also used. The system estimates the size and number of machine, power requirement and fuel consumption for the implements and operations. Verification showed that, the system has the ability to estimate the required parameters as soon as input data was entered. System validation indicated no significant differences between predicted results and actual data. The sensitivity analysis showed that, changing of input variables affects the output parameters and consequently selection is possible. The system was applied to estimate the required output variables in the mechanized rainfed agriculture in Gedarif, Sudan. It can be used for proper crop and machinery management as pre-season decision making with great confidence.

Key words: Crop production, machine selection, farm management, computer system.

INTRODUCTION

Farm mechanization is the use of machines for production process. Crop production involves sequence of actions, operations and other factors that affect production. A good farm management plan has to analyze the whole farming system for maximizing production and minimizing risks. The farm manager has to study the relationships between machines, weather and crop combinations. Management can more or less control machine capacity (machine width, speed, and field efficiency), as well as selection of implement, operation and crop. Computer systems can facilitate the examination of these relationships.

Many computer systems were developed elsewhere to analyze the factors that affect field operations and machinery performance. The purposes of these systems varied from power selection and implement matching (Dahab and Mohamed, 2006; Alam et al., 2001; Bol et al., 2006; Yousif and Dahab, 2010), to systems incorporate farm size, cropping patterns, soil properties and climatic conditions to calculate tractor power, machine width and estimating costs (Isik and Sabanci, 1993; Ismail and Burkhardt, 1994). Other systems deal with special crops (Parmar et al., 1994; Dahab and O'Callagham, 1998).

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Management of rainfed agriculture is a complex process. The complexity is due to the nature of various and interrelated factors involve in crop production process. These factors include; selection of crops and agricultural machinery (tractors and implements), the expected working time for field operation, inputs cost and outputs prices. It is believed that, promotion of farm management can be realized by the use of modern techniques like computer and softwares. Computer systems can facilitate the process of planning and decision making. Therefore, a computer system was developed to be used as a tool for crops -machinery management. The goals of the system were to select the number and size of machinery (tractor and implement) required to perform timely seedbed preparation, seeding and weed control operations for 4 crops; sorghum, sesame, sunflower and cotton grown in 1, 2, 3, and 4 crops combination.

MATERIALS AND METHODS

Characteristics of the study area

The study was conducted in Gedarif State, which lies in the Eastern part of the Sudan between latitudes 12.67 and 15.75°N and longitudes 33.57 and 37.0°E, where about more than 3 000 000 ha are put under cultivation. The soil is heavy cracking clay soils (Vertisols), which was characterized by shrinking when dried and swelling when moistened. The clay content ranged between 65 and 75%.

Crops grown and field operations

Sorghum is a dominant grown crop, constitutes about 85% of the cropped area, followed by sesame, while sunflower and cotton are sown in limited areas where rain amount is sufficient for their growth. Land preparation and seeding operations usually start when the accumulative rainfall reaches about 100 to 125 mm, which is sufficient for establishing crops. This usually occurs during the second and third week of July. The wide level disk plow is the main machine used for seedbed preparation and seeding operations. However, deep plowing (chiseling) and shallow plowing (disk harrowing) and row crop planter are sometimes practiced in limited areas. Weed control usually starts 2 to 4 weeks after crops germination. Hand weeding is the common practice, however, due to shortage and high expense of labors, mechanical weed control (Sarwala operation) by WLD as well as herbicides application are recently adopted. Tractors of 75 to 80 ha are the main source of farm power; however, big tractors were recently introduced to operate large and heavy implements for improving timeliness of agricultural operations. According to the used machinery and cultural practices there are three farming system practiced; namely conventional, zero-tillage and heavy machinery farming systems. The mechanized farming system consists of large commercial farms 210 to 420 ha or more.

Data collection and analysis

The required input data to run the developed system is collected from many sources, such as agricultural engineers, Agricultural Research Corporation (ARC) Reports, Mechanized Farming Corporation (MFC), field observations, ASABE standard, John Deer publications, and agricultural machinery dealers. The collected data include; crops and their operations and type and size of machine, field efficiency, speed, draft requirement, machinery capacity, fuel consumption rates.

Statistical measures employing mean, standard deviation, maximum and minimum, correlation analysis were used as data analysis tools. Also, T-test was used to compare and test the significance between the predicted and actual data. Moreover, the Root mean square error (RMSE) criterion was used to compare the values of the predictions and actual data. The RMSE was calculated as follows:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n=5}\left(\left(predicted\right)_i - \left(actual\right)_i\right)^2}$$

Where: n = number of observation, i = different, predicted = unit predicted values and actual = actual values.

Computer system development

System structure

The system was developed in Excel and Visual basic computer softwares. Data entry is a step by step process in specifically designed cells. The user is always given the freedom to use site specific data or use built-in data. Data input can be corrected done directly on screen. The system output can be displayed on the screen or as print out.

System description

The crop production and farm machinery combination management system was designed to work with a sequence of procedures, crop and implement procedure, farm machinery management procedure and farm costs analysis procedure. All procedures work collectively. The system flow chart was described in Figure 1.

Crop and implement selection procedure

This is the basic procedure for the whole system, which allows the user to choose crops and required field operations. The designed options of crops were 1, 2, 3, or 4 crop combinations. The designed crops were sorghum, sesame, sunflower and cotton. The system deals with 3 operations; seedbed, seeding, and weed control; via 6 implements namely; chisel plow, disk harrow, wide level disk, row-crop - planter, inter-row-cultivator and sprayer. The wide level disk with the seeder box may be used for seedbed, seeding and weed control (Sarwala) operations. The user has to enter the

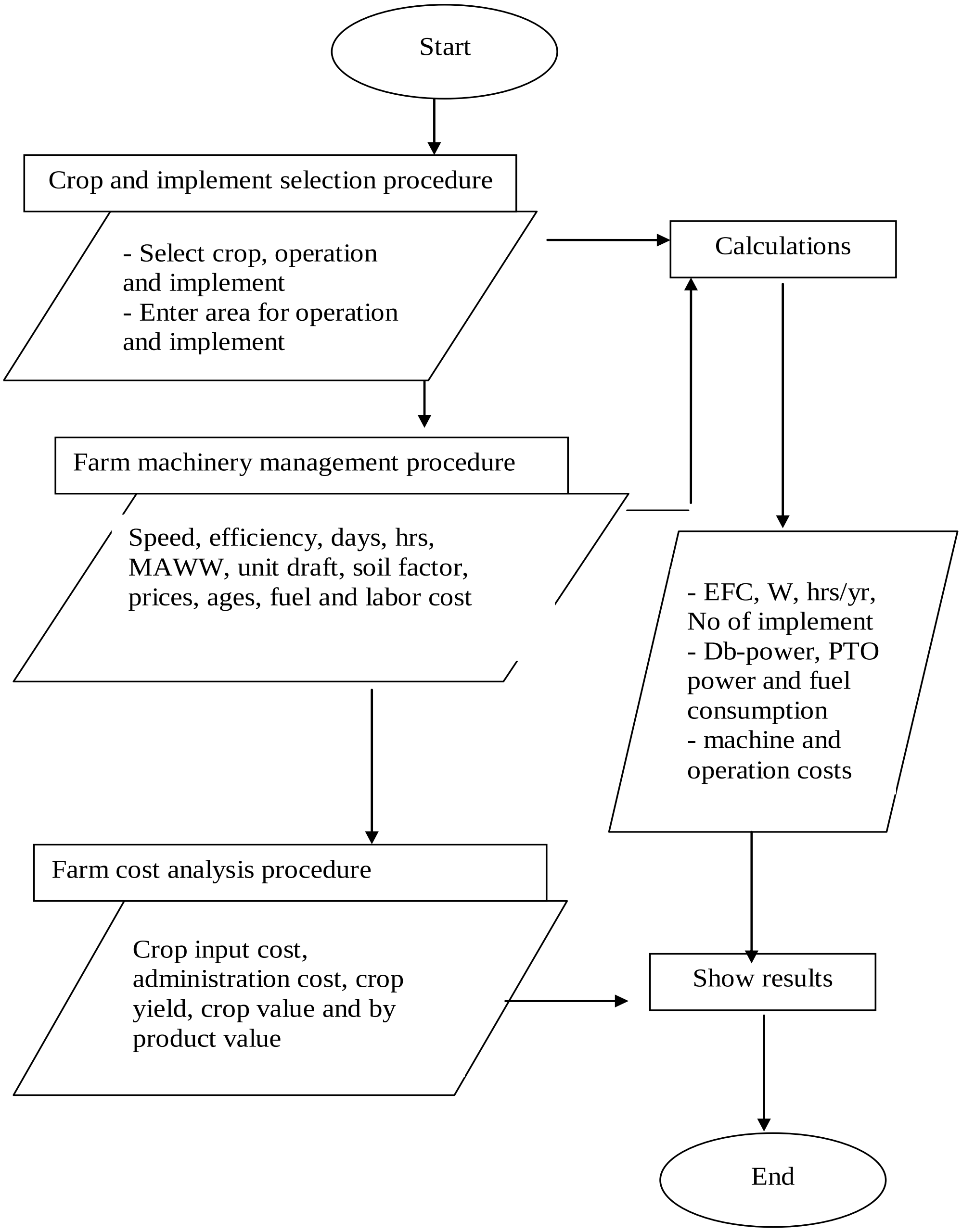

Figure 1. Crop and machinery management unit flow chart.

area (ha) to be cultivated across each crop, operation and machine. The system computes the total cultivated area for each crop according to the selected seedbed preparation methods. Also, the system computes the total area of each implement for all crops or operations.

Machinery management procedure

This procedure deals with machinery (implements and tractor). It uses the intended operations, area to be covered and implement type that had been specified in the crop production procedure. It consists of 3 sub-procedures; machinery selection, power requirement and machinery costs.

The machinery selection sub-procedure computes the size and the number of implements and power units required to complete field operations during specific period of time by computing effective field capacity (ha/h). The required input data include: speed of field operation, field efficiency, available working days, and available working hours per day.

The machinery power requirement sub-procedure determines the required drawbar power (kw), tractor PTO power (kw) and fuel consumption (L/h) for the selected implement. The required input data include: unit draft (kn/m) and soil condition factor.

Implement selection calculations

Field capacity

The effective field capacity (EFC) (ha/h) is calculated using total area and total available time as follows:

$$EFC\ (ha/h) = A/(D \times h) \quad (1)$$

Where: A = area under operation (ha), D = available working days and hr = available working hours per day.

Required width

The required working width (W) (m) of a machine is calculated as follows:

$$W = (EFC \times C)/Se \quad (2)$$

Where: C = conversion factor = 10, S = field speed (km/hr) and e = field efficiency of the machine, decimal.

Number of machine(s) required

The number of the machine(s) required is calculated as follows:

$$\text{Number of M} = W/MAWW \quad (3)$$

Where, Number of M = number of machine required and MAWW = maximum available working width (m).

Machinery power requirement

Drawbar power

The drawbar power (DBHP), (kw) for an implement is calculated as follows:

$$DBHP = (S \times D \times W)/ 3.6 \quad (4)$$

Where: D = Unit draft (kn/m)

Tractor take – off shaft power

Tractor PTO required power (TPTO) is calculated using implement drawbar power and soil condition factor as follows:

$$TPTO = DBHP \times \text{soil condition factor} \times 1.25 \quad (5)$$

Fuel consumption

Fuel consumption for diesel engine is calculated according to the method described by (FMO, 1976) as follows:

$$\text{Fuel consumption (L/hr)} = DBHP\ (kw) \times 0.226 \quad (6)$$

RESULTS AND DISCUSSION

System verification

The system was verified for the implement width, effective field capacity, drawbar power, required PTO power and fuel consumption by using published data from Sumner and William (2007) as shown in Table 1. It was observed that, as soon as entering input data the unit displays the results. The predicted results were identical to that obtained by Sumner and William (2007). This means that, the unit is able to calculate the required parameters correctly.

System validation

The system validity was tested for the five implements to compare between actual and predicted effective field capacity (ha/h), implements width (m) and fuel consumption (L/h) as shown in Table 2. The root mean square of the error criterion was used as a comparison measure. The results showed very low RMSE (0.179), (1.095), and (0.1612) between the predicted and actual data for effective capacity, implements width (m) and fuel consumption (L/h), respectively (Table 2). Moreover, Paired T-test indicates no significant difference (at 5%) between the system predictions and actual data (Table 3). These indicate a high consistency between actual data and the system predictions.

System Sensitivity analysis

Effect of changing cropped area on number of implement

Increasing cultivated area from 420 to 3780 ha, the number of machines changed from 1 machine to 3, 6, 9, 9, 5, and 3 machines for wide level disk, disk harrow, chisel plow, row crop planter, inter-row cultivator and sprayer, respectively (Table 4). The results demonstrated that, chisel plow and row crop planter are highly sensitive to the changes in area. This may be due to their effective width, working speed or available working hours per day.

Table 1. Verification of the unit with published data.

Input variable	**Input data for Sumner and William (2007) and the model**	
Implement name	Disk harrow	
Area, ha	49	
Days	5	
Hours/day	8	
Speed Km/h	8.1	
Efficiency, decimal	0.82	
Maximum available width, m	1.8	
Unit draft, kn/m	5.37	
Output parameter	**Sumner and William (2007)**	**Model prediction**
Implement width, m	1.82	1.80
Effective field capacity, ha/h	1.21	1.20
Drawbar power, kw	21.94	21.75
Required PTO power, kw	46.12	46.00
Fuel consumption, L/h	10.00	10.00

Table 2. Comparison between predicted and actual field capacity (ha/h).

Machine name	**Field capacity (ha/h)**		**Fuel consumption (L/h)**		**Implement width (m)**	
	predicted	**actual**	**predicted**	**actual**	**predicted**	**Actual**
Wide level disk	2.7	2.9	11	12	3.6	3.7
Offset disk harrow	1.4	1.5	11	13	1.6	1.7
Chisel plow	1.3	1.4	13	13	1.9	2
Row crop planter	1.9	1.8	12	13	3.3	3.2
Sprayer	9.6	9.9	0.2	0.2	13.7	14
RMSE	0.179		1.095		0.1612	

RMSE = root mean square of the error.

Table 3. T-test for the mean difference of the evaluation indicators for system outputs and field data.

Statistical parameter	**Field capacity (ha/h)**	**Fuel consumption (L/h)**	**width (m)**
Variance of the difference between the means	0.0044	0.1400	0.004
Standard deviation of the difference	0.0663	0.3742	0.0632
Effective degree of freedom	4	4.0	4.0
Probability of t	0.1447	0.0993	0.1890
f-calculated	1.0661	1.1578	1.0418
T-calculated	-1.8091	- 2.1381	-1.5811
T-tabulated	2.776	2.776	2.776

On the other hand, WLD and sprayer are less sensitive to the changes in cultivated area.

Effect of changing annual workdays on implements width

The system was used to determine optimum machine width when changing annual working days. The results showed that, at specific cultivated area (e.g., 420 ha), changing annual working days changed the required width of each implement. This helps the farm manager to select the suitable working width of a machine according to the available working days and farm size. The results also indicated that, the predicted working width for all studied machines decreased as annual working days

Table 4. Effect of changing cropped area on number of machines for different operations.

Area (ha)	WLD	DH	CP	RCP	IRC	SP
420	1	1	1	1	1	1
1260	1	2	3	3	2	1
2100	2	3	5	5	3	2
2940	2	4	7	7	4	2
3780	3	6	9	9	5	3

WLD = wide level disk, DH = disk harrow, CP = chisel plow, RCP = row crop planter, IRC = inter-row cultivator and SP = sprayer.

Table 5. Effect of changing workdays on machines width.

Working days	WLD	DH	CP	RCP	IRC	SP
9	3.6	3.2	3.8	8.0	5.0	7.6
12	2.7	2.4	2.9	6.0	3.7	5.7
15	2.2	1.9	2.3	4.8	3.0	4.6
18	1.8	1.6	1.9	4.0	2.5	3.8
21	1.5	1.4	1.6	3.4	2.1	3.3
24	1.4	1.2	1.4	3.0	1.9	2.8
27	1.2	1.1	1.3	2.7	1.7	2.5
30	1.1	1.0	1.1	2.4	1.5	2.3
33	1.0	0.9	1.0	2.2	1.4	2.1

*Using total area of 420 ha, WLD = wide level disk, DH = disk harrow, CP = chisel plow, RCP = row crop planter, IRC = inter-row cultivator and SP = sprayer.

Table 6. Effect of changing soil factor on power required (kw) for different machines.

Soil factor	WLD	DH	CP	RCP	IRC
Firm (1)	51	42	58	43	29
Tilled (2)	61	50	69	52	35
Sandy or soft soils (3)	71	59	81	60	41

WLD = wide level disk, DH = disk harrow, CP = chisel plow, RCP = row crop planter and IRC = inter-row cultivator

increased (Table 5). This confirms the fact that, there is a reverse relationship between cultivated area and working time.

Effect of changing soil type on implements power requirements

The system offers the user three choices for changing soil conditions which are firm, tilled and sandy or soft soils, and then the system computes the required drawbar power for the selected implements. Table 6 shows the effect of changing soil condition factor on power requirements for the selected implements. For all tested implements, the power requirements in Kilowatts increased as soil factor changed from firm to tilled and sandy or soft soils.

Effect of the cropping system on power requirement and fuel consumption

The results showed that, conventional farming system gave the smallest values of power required, fuel consumed as well as operation cost per hour and per hectare (Table 7). These findings explain why farmers still hold on to conventional cropping system. In contrast heavy machinery system resulted in the highest values of the mentioned parameters. In this regard, Alam et al. (2001) found that, optimum power level varied with the size of farmland and cropping patterns. However, zero tillage seems to be time effective and can be used as a

Table 7. Effect of cropping system on tractor annual working hours, power requirement, fuel consumption and operations cost.

Cropping system	Tractor annual working hour	Maximum fuel consumption L/ha	Maximum power required (kw)	Operation cost (SDG/h)	Operation cost (SDG/ha)
CFS	468	11	51	123.05	46.19
ZTFS	310	12	52	394.08	122.81
HMFS	589	13	58	494.88	178.88

CFS = conventional farming system, HMFS = heavy machine farming system, ZTFS = zero tillage farming system.

farming system when all requirements for its successes are available. These results can help the user in pre season planning and management.

Conclusions

A computer system for crop-machinery management was developed. The developed system is user-friendly and could be run on most available computers. The system was validated and statistically analyzed by comparing the predicted output to the actual data and its accuracy was approved. The system can quickly be used to explore the effect of changing one or more of input parameters on output variables, and thus can help in quick decision-making. The system can be used as pre-season planning and management tool.

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UPCOMING CONFERENCES

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