academicJournals

Vol. 8(44), pp. 5592-5598, 14 November, 2013
DOI: 10.5897/AJAR2013.7969
ISSN 1991-637X ©2013 Academic Journals
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Nutrients uptake ability of various rainy season crops grown in a vertisol of central India

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Accepted 30 October,2013

A pot culture experiment was conducted at Indian Institute of Soil Science to compare the nutrient uptake pattern of rainy season crops such as maize, soybean, sorghum, pearl millet, finger millet and rice. Crop biomass was taken at 30, 50, 75 and 90 days after sowing (DAS) and at maturity from each crop. Among the crops grown, total dry biomass was decreasing in the following order; maize > pearl millet > sorghum > soybean> rice > finger millet. With respect to nutrient uptake, soybean crop showed highest nitrogen (N) content in shoot (1.73%), followed by maize (1.12%), pearl millet (1.10%), finger millet and rice (0.79%) and sorghum (0.78%), whereas, maximum phosphorus (P) concentration was in maize followed by pearl millet and sorghum. Micronutrient concentration was more in shoot as compared to roots in all crops except soybean. This study might be useful in the bio-fortification process for fodder purpose. Higher biomass producing maize crop with higher nutrient uptake capacity can be used for agronomic biofortification. It will help for reducing nutritional deficiency in animals.

Key words: Biomass, nutrient uptake, soil fertility.

INTRODUCTION

Agriculture is the backbone of Indian economy. Its production and productivity is affected by soil, environment, and social factors. The soil nutrient status affected the crop biomass and nutrient uptake by crops. Rainy season crops play a sustainable role to maintain Indian food stocks. In general, rainy season refers to the planting, cultivation and harvesting of any domesticated plant sown in the rainy (monsoon) season on the Asian subcontinent (Benbi, 2010). These crops are better known as the monsoon crops in Indian sub continent (India, Pakistan Sri Lanka and Nepal). These crops are sown with the onset of monsoon towards the end of May in the state of Kerala during the advent of south-west monsoon. *Sorghum bicolor* is an important cereal crop, used for food, fodder, the production of alcoholic beverages, and biofuels. Most of the sorghum varieties are drought and heat-tolerant, and are especially grown in arid regions, where the grain is one of the staples for poor and rural people.

Soil act as a sink or source of CO_2 depending on land management. It can potentially store some of the atmospheric CO_2 fixed by crop plants and hence helps to mitigate greenhouse gas emissions from the agricultural sector (Kundu et al., 2013). Crop biomass and nutrient content in plant is mostly governed by physio-chemical reaction of nutrient in soil as well as genetic potential of crop (Rajendiran et al., 2012). Higher biomass production indicates the balance supply of crop required nutrient to plant. It enhanced the plant nutrient uptake and crop yield (Yadav and Solomon, 2006). Sometime nutrients are not transferred to the biological part, and reduced crop yield adversely. Higher biomass production enhanced the

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Table 1. Physico-chemical properties of experimental soil.

Particular	Values
pH (pH $_w$ 1:2)	8.06
Electrical Conductivity (dS m^{-1})	0.57
Soil organic C (%)	0.44
Available Nitrogen (kg ha^{-1})	175
Available P (kg ha^{-1})	7.53
Available P (kg ha^{-1})	185
Available Sulphur (kg ha^{-1})	9.09
DTPA Extractable (ppm)	
Zn	0.90
Fe	5.32
Mn	5.22
Cu	1.46

nutrient uptake by the crop, because it secreted the root exudates into the soil. The plant root exudates contributing significant amount of Carbon (C) to the soil. The exudates play an important role in C flow in the soil-plant system; 16 to 33% of the C assimilated by plants through photosynthesis is transferred into the soil through the roots (Dotaniya et al., 2013a).

MATERIALS AND METHODS

Location and climate

A pot culture study was conducted at the Division of Environmental Soil Science, Indian Institute of Soil Science (IISS), Bhopal, India. Geographically, The Bhopal is situated at 23°18'N, 77°24' E and 485 m above mean sea level. It has semi-arid and sub-tropical dry summer and cold winter climate with a mean annual air temperature of 25°C and annual rainfall of 1208 mm.

Collection and processing of soil for pot experiment

Soil for the pot experiment was collected from the field of the IISS, Bhopal. Soil samples were taken randomly from the farm up to a depth of 15 cm, with the help of soil auger and a composite sample was obtained by mixing them thoroughly. The collected soil was air dried and ground by using pestle and mortar, and passed through a 2 mm sieve. The processed soil was filled in plastic pots. The experimental soil was analyzed for its physico-chemical properties. The experimental soil belongs to Vertisols that is, Hypothermic family of *Typic Haplusterts* popularly known as “black cotton soil”.

Physico-chemical properties of experimental soil

The data on mechanical analysis is given in Table 1 which indicate that, the experimental soil was clay loam in texture. The chemical composition of soil indicated that, the experimental soil contains low range of organic C, Nitrogen (N), Phosphorus (P) and medium range of Potassium (K). In the available micronutrients particularly Zinc (Zn) was deficient and Iron (Fe), Copper (Cu), Manganese (Mn) was medium in their availability. Bulk density was higher and water holding capacity was also good.

Pot culture experiments

The pot culture experiment was conducted using six crops *viz*. maize, soybean, sorghum, pearl millet, finger millet and rice having different genetic potential (Table 2). The processed soils were filled in 90 pots at 10 kg/pot. Five crop varieties were sown and rice seedlings were transplanted in each pot in a manner that each treatment should be replicated for 3 times. The seeds of different crops were collected from JNKVV Jabalpur, India.

Sowing

Healthy and bold seeds of crops were soaked in water for 24 h. After soaking, seeds were taken out from water and placed on floor for squeezing free moisture. The soaked seed were treated with thiram at 0.5 g/100 g of seeds and 5 g culture kg^{-1} seed with the help of sugar jaggery paste. Total 25 to 30 healthy soaked seeds were sown in each pot at optimum field capacity moisture. Seeds were placed at equal distance at the depth of 3 to 4 cm and covered with dry soil to avoid any damage. After establishment, germination of seedling was counted to know damage. Seedlings were thinned to desired plant population (3 plants) per pot. The pots were frequently irrigated with deionized water as per requirement.

Nursery management and transplanting of rice

The nursery was raised in selected pots filled with soil up to the level of the rim. Basal dose of nutrients were applied and flooded with water. Then rice seeds were sown in 15 different pots at the depth of 2 cm. Before sowing, seeds were treated with thiram at 0.2 g/100g of seeds. 100 seeds were sown in a pot. Seeds geminated for 4 to 5 days after sowing (DAS). In the beginning, light watering was given daily with the help of water can. About 2 g DAP fertilizer was sprayed per pot. The 21 days old aged seedlings were transplanted. In each pot 3 plants were maintained with equal spacing.

Table 2. Characteristic features of crop cultivar.

Crop	Cultivars	Characteristics
Sorghum	NJH- 21	High yielding, drought tolerance, fatty acid composition 2.1 - 5.3%, total saturated fatty acid 10.52%.
Soybean	JS- 335	High yielding and early maturity, resistant to bacterial pustule, bacterial blight, susceptible to yellow mosaic virus.
Rice	Kranti	The scientific name of this variety is R-2022. It is best grown in irrigated areas. The grain is short bold and white.
Maize	P-3540	Higher production, Insect and acid resistant, suitable for rainfed cultivation.
Pearl millet	VBBH-3115	Highly resistant to downy mildew, more number of synchronous tillers, long and very compact heads.
Finger millet	V- 10	Blast resistant, total sugar reducing, High production.

Fertilizer application

The crops were fertilized as per the requirement of treatments viz, the fertilizers were applied with the recommended dose (kg/ha) of N, P, and K [100:60:60 for sorghum, rice, maize and pearl millet; 30:60:40 for soybean and 60:40:40 for finger millet through urea, DAP and MOP]. N is applied in two split doses. Half dose of urea and full dose of DAP and MOP were applied at the time of sowing in rice, maize, sorghum, pearl millet and finger millet as basal dose except soybean where full dose of urea, DAP and MOP applied as basal dose. A basal application of Zinc sulphate (Zn 7 kg/ha) for all crops except rice (10 kg/ha was applied at the time of sowing. The remaining half dose of N was applied to rice, maize, sorghum, pearl millet and finger millet at 30 days after sowing.

Biomass

Biomass was taken at 30, 50, 75 and 90 DAS and at maturity for all crop. At all time intervals, 3 pots were taken out from each crops as destructive method, plants washed with distilled water and collected in paper bags. The roots (R) and shoots (S) were separated with the help of scissors and kept in separate paper bags. These plant parts further allowed to air dry for 2 to 3 days and then placed in hot air oven at 60°C for 24 h. Dry matter of shoot and root were recorded and samples were drawn for analytical work. Estimation of total N, P, K, S and diethylene triamine pentaacetic acid (DTPA) extractable micronutrients were done with the help of standard methods (Singh et al., 2005).

Nutrient uptake

Nutrient uptake by different crops was calculated in g/plant in relation to biomass yield by using the following formula:

$$\text{Nutrient uptake (g/plant)} = \frac{\text{Nutrient content (\%)} \times \text{plant biomass yield (g)}}{100}$$

Statistical analysis

The data obtained were subjected to statistical analysis using standard method that is, Completely Randomized Design (CRD) described by Gomez and Gomez (1983).

RESULT AND DISCUSSION

Plant biomass

Shoot, root and total plant biomass (g/plant) of all crops at different time intervals viz.30, 50, 75, 90 DAS and at maturity were measured by destruction method (Figure 1). Data shows that, biomass was increased with time interval up to 90 DAS after that, it decline at crop maturity in all the crops. During the course of investigation, total plant biomass varied in maize crop from 15.82 to 39.91 g while, pearl millet (10.75 to 33.86 g), sorghum (7.46 to 28.6 g), rice (4.14 to 21.8 g), finger millet (3.53 to 21.50 g) and soybean (4.56 to 17.29 g), respectively.

Total plant biomass was highest recorded at 90 DAS in all crops. Several studies have indicated that, soil N availability, although strongly altering shoot growth, does not significantly affect the dynamics of root growth at depth (Molina et al., 2001). Among all crops, maize contributed maximum root biomass (10.64 g) followed by pearl millet, rice, finger millet, sorghum and soybean crops, respectively. The balance fertilizer enhanced the C sequestration rate, and increase was more in maize-wheat cropping system (Kukal et al., 2009). These results also fulfill the hypothesis of growth curve, in which plant attained maximum biomass and after it slightly decline (Lal et al., 1997; Benbi, 2010).

Major nutrient uptake

The major nutrient concentration (%) estimated at crop maturity and data showing variation in N, P, K, and S concentration in root and shoot (Table 3). In case of N,

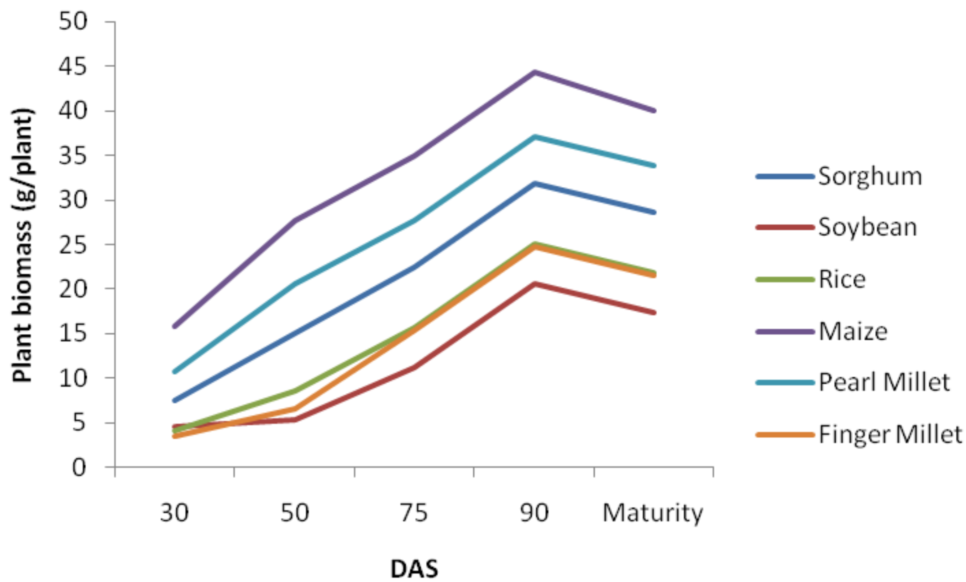

Figure 1. Biomass production of various different rainy season crops at different time interval

Table 3. Macro nutrient concentration (%) at crop maturity.

Crop	Nitrogen		Phosphorus		Potassium		Sulphur	
	S	R	S	R	S	R	S	R
Sorghum	0.78	0.10	0.13	0.11	1.44	1.24	0.10	0.14
Soybean	1.73	0.54	0.16	0.15	2.02	1.21	0.13	0.31
Rice	0.79	0.20	0.13	0.12	1.87	0.62	0.12	0.26
Maize	1.12	0.22	0.23	0.14	3.40	2.46	0.14	0.23
Pearl millet	1.10	0.12	0.10	0.12	1.46	1.16	0.10	0.24
Finger millet	0.79	0.20	0.12	0.09	1.31	1.20	0.11	0.13
CD(P = 0.05)	0.01	0.02	0.03	0.02	0.42	0.24	0.02	0.09

(S:shoot, R:root).

soybean crop showed highest N content in shoot (1.73%), followed by maize (1.12%), pearl millet (1.10%), finger millet and rice (0.79%) and sorghum (0.78%). There were no significant differences found between rice and finger millet crop. In case of root N concentration, it was also highest in soybean crop followed by maize, rice, finger millet, pearl millet and sorghum, respectively. All crops significantly differ from each other in case of shoot N content but in case of root N content soybean are superior over the others. P concentration in shoot was maximum in maize (0.23%), followed by soybean (0.16%), sorghum (0.13%), rice (0.13%), finger millet (0.12%) and pearl millet (0.10%), respectively whereas, root P concentration was maximum in soybean (0.15%), followed by maize (0.14%), pearl millet (0.12%), rice (0.12%), sorghum (0.11) and finger millet (0.09%), respectively.

P concentration in shoot varied from 3.40 to 1.31%. The highest K concentration was found in maize (3.40 %) followed by soybean (2.02%), and rice (1.87%) which is significantly differ from pearl millet (1.46%), sorghum (1.44%) and finger millet (1.31%). In case of roots, highest K content was in maize (2.46%), followed by sorghum (1.24%), soybean (1.21%), finger millet (1.20%), pearl millet (1.16%) and rice (0.62%), respectively. Sulphur (S) concentration also varies from 0.10 to 0.14% in shoot and 0.13 to 0.31% in root. Among the crops, maize showed highest S concentration (0.14%) in shoot followed by soybean, rice, finger millet, sorghum and pearl millet but in case of root it was maximum in soybean (0.31%), followed by rice, pearl millet, maize, sorghum and finger millet, respectively. No significant difference was found between sorghum and pearl millet in S shoot concentration at crop maturity. Higher nutrient concentration in pulses compared to cereals was also observed (Dotaniya et al., 2013b). Its root system absorb

Table 4. Macro nutrient uptake (g/plant) at crop maturity.

Crop	Nitrogen			Phosphorus			Potassium			Sulphur		
	S	R	T	S	R	T	S	R	T	S	R	T
Sorghum	0.18	0.01	0.19	0.03	0.01	0.04	0.34	0.06	0.40	0.02	0.01	0.03
Soybean	0.24	0.02	0.26	0.02	0.01	0.03	0.28	0.04	0.32	0.02	0.01	0.03
Rice	0.13	0.01	0.14	0.02	0.01	0.03	0.29	0.04	0.33	0.02	0.02	0.03
Maize	0.33	0.02	0.35	0.07	0.02	0.09	0.51	0.14	0.65	0.04	0.02	0.07
Pearl millet	0.28	0.01	0.25	0.03	0.01	0.04	0.37	0.10	0.47	0.03	0.02	0.05
Finger millet	0.12	0.01	0.13	0.02	0.01	0.02	0.20	0.07	0.28	0.02	0.01	0.03
CD (P = 0.05)	0.055	0.002	0.056	0.010	0.001	0.011	0.108	0.021	0.123	0.008	0.006	0.009

(S:shoot, R:root, T:total).

higher amount of plant nutrient from soil solution.

The N, P, K, and S uptake by plant was one of the important parameter during the study. Uptake pattern depends on plant biomass and nutrient concentration in plant part. In all the crops shoot uptake was more than root with respect to N, P, K and S. Total N uptake was maximum in maize crop (0.35g), followed by soybean (0.26g), pearl millet (0.25g), sorghum (0.19g), rice (0.14g) and finger millet (0.13g) (Table 4). In case of P uptake, the maximum uptake was recorded in maize (0.09g), followed by sorghum (0.04g), pearl millet (0.04g), rice (0.03g), soybean (0.03g) and finger millet (0.02g). Among the crops, P uptake in maize crop significantly higher than others. P uptake was also high in maize crop due to higher uptake of K by roots and shoots. It was varied from 0.65 g/plant in maize to finger millet in lower side (0.28 g/plant). Sorghum (0.40g), rice (0.33) and soybean (0.32g) do not differ significantly with respect to K uptake. S uptake was maximum in case of maize (0.07 g/plant). It was significantly differ from other crops and finger millet had lowest uptake (0.03 g/plant) at maturity. Sorghum, soybean and rice do not significantly differ in S uptake. The higher nutrient uptake might be due to higher biomass yield in maize crop. The plant root exudates secreted and enrich the rhizospheric soil and hence enhanced the nutrient uptake by the crops (Dotaniya et al., 2013c). Similar findings were also reported by Bennett (1953), Viets et al*.* (1954) and Hussaini et al. (2001).

Micro nutrient uptake

Data on micronutrients concentration at maturity presented was in Table 5. Results showed that, Zn concentration was maximum in rice shoots (30.22 ppm) followed by soybean, maize, sorghum, pearl millet, and finger millet. Soybean and maize crops do not show any significant difference in shoot Zn concentration. In case of roots, soybean crop showed maximum Zn concentration (31.47 ppm) followed by rice, maize, sorghum, finger millet and pearl millet. Among the crops, rice and maize; pearl millet and finger millet did not show any significant different from each other. Soybean showed maximum Fe concentration in shoot and root followed by sorghum, pearl millet, finger millet, rice and maize. No significant difference was observed both in rice and maize; pearl millet and finger millet from each other. But in manganese concentration in shoots was varied from 0.48 ppm in soybean to 0.19 ppm in finger millet. In case of root Mn concentration, it was varied from 0.46 to 0.17 ppm. Soybean showed maximum Mn concentration in roots as well as in shoots, followed by rice, sorghum, pearl millet, maize, and finger millet. The Cu concentration in shoots was varied 0.63 to 0.24 ppm. It was maximum for maize crop (0.63 ppm) followed by rice, pearl millet, sorghum, soybean, and finger millet. In case of root Cu concentration, maize also attained a maximum (0.51 ppm) followed by soybean (0.44 ppm), sorghum (0.34 ppm), pearl millet (0.33 ppm), rice (0.33 ppm) and finger millet (0.20 ppm) at maturity.

Micronutrient uptake in shoot and root was varied from crop to crop (Table 6). The Zn uptake was varied from7.95 mg/plant in maize to 3.66 mg/plant in finger millet in shoots and 0.11 mg/plant in maize to 0.04 mg/plant in soybean roots The total Zn uptake was recorded maximum in maize (8.05 mg/plant), followed by pearl millet, sorghum, rice, soybean and finger millet. But in case of Fe uptake, it was different from Zn. Among the crops, pearl millet was recorded highest Fe uptake (0.73 and 0.23 mg/plant) in shoot and root, followed by sorghum, maize,

Table 5. Micro nutrient concentration (%) at crop maturity.

Crop	Zn		Fe		Mn		Cu	
	S	R	S	R	S	R	S	R
Sorghum	22.14	19.37	3.11	3.59	0.33	0.31	0.50	0.34
Soybean	27.47	31.47	3.55	3.69	0.48	0.46	0.46	0.44
Rice	30.22	20.18	2.16	2.36	0.37	0.28	0.56	0.33
Maize	27.13	20.02	2.17	2.30	0.23	0.27	0.63	0.51
Pearl millet	21.35	17.03	2.88	2.83	0.26	0.22	0.51	0.33
Finger millet	19.62	17.69	2.70	2.81	0.19	0.17	0.24	0.20
CD (P = 0.05)	1.50	1.82	0.25	0.36	0.07	0.08	0.03	0.04

(S:shoot, R:root).

Table 6. Micro nutrient uptake (mg/plant) at crop maturity.

Crop	Zn			Fe			Mn			Cu		
	S	R	T	S	R	T	S	R	T	S	R	T
Sorghum	5.20	0.05	5.25	0.73	0.19	0.91	0.08	0.02	0.09	0.12	0.02	0.14
Soybean	3.79	0.04	3.82	0.49	0.13	0.62	0.07	0.02	0.08	0.06	0.02	0.08
Rice	4.76	0.06	4.82	0.34	0.15	0.49	0.06	0.02	0.08	0.09	0.02	0.11
Maize	7.95	0.11	8.05	0.63	0.25	0.88	0.07	0.03	0.10	0.19	0.05	0.24
Pearl millet	5.50	0.08	5.58	0.73	0.23	0.96	0.07	0.02	0.09	0.13	0.03	0.16
Finger m illet	3.66	0.07	3.09	0.42	0.17	0.59	0.03	0.01	0.04	0.04	0.01	0.05
CD (P = 0.05)	1.71	0.01	1.36	0.11	0.03	0.11	0.02	0.00	0.02	0.03	0.00	0.03

(S:shoot, R:root, T:total).

soybean, finger millet and rice. ll the crops significantly differ with respect to Fe uptake from each other. Among all the crops, sorghum shoot (0.08 mg/plant) and maize root (0.03 mg/plant) were recorded maximum uptake of Mn at maturity. There was no significant effect found between sorghum, soybean, rice and pearl millet in root Mn uptake but in case of total Mn uptake, it differs significantly in all the crops except soybean and pearl millet. Cu uptake was more by shoots as compare to roots. The value for Cu uptake was varies from 0.19 mg/plant in maize and 0.04 mg/plant in finger millet shoots but total uptake was more in maize (0.24 mg/plant), followed by 0.16, 0.11, 0.08 and 0.05 mg/plant for pearl millet, sorghum, rice, soybean and finger millet, respectively at maturity. Higher biomass producing crops secreted higher amount of organic substances in the soil, which act as a chelating agent for the enhancement of micronutrients (Dotaniya et al., 2013a). Decayed plants parts released the micro nutrient carrying organic molecules, and accelerate the micronutrient uptake by plant (Dotaniya and Datta, 2013). Similar results were also found by Shuman (1998) and Gupta (1992).

The rainy season crops can produced huge amount of biomass which helps in C sequestration. Micro and macro nutrient concentration in plant parts showing the capacity of a particular crop to acquire nutrient from soil. On the basis of crop uptake capacity, we can go for biofortification for a particular crop. This study helps to understand the uptake pattern of rainy season crops in respect to biomass yield. Maize crop gave higher biomass and it can be used for biofortification for fodder purpose.

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