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EFFECT OF NUTRIENT MANAGEMENT MODULES ON YIELD OF HYBRID RICE AND NUTRIENT AVAILABILITY OF RECLAIMED ALKALI ALLUVIAL SOIL AT VARIOUS GROWTH STAGES OF RICE

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ABSTRACT

A study was conducted to evaluate the effect of nutrient management modules on yield of hybrid rice and nutrient availability of alluvial soil at various growth stages of rice. Results showed that highest grain yield was recorded under nutrient management module of 100% NPK + 5 t pressmud (T_3) closely followed by 100% NPK + 10 t FYM (T_2). Maximum buildup of organic carbon content of soil and considerable reduction in pH and EC was observed under T_3. An improvement in available N, P, K and Zn content of soil at tillering, panicle initiation and harvest stage was estimated under all the plots treated with pressmud, FYM, water hyacinth, green manure and BGA along with different levels of inorganic fertilizer over inorganic fertilizer alone. Maximum N, P, K, S and Zn availability at tillering, panicle initiation and harvest stage was estimated under T_3 closely followed by T_2. Available nutrients in soil recorded maximum at tillering stage which reduced progressively towards the maturity of the crop. Among the various nutrient management module treatment T_3 resulted higher yield. Soil properties like organic carbon content, available N, P, K, S and Zn were also improved to considerable extent with the same treatment.

KEY WORDS
Hybrid rice yield
Nutrient management module
Soil properties
Nutrients availability

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INTRODUCTION

Rice is the principal and prime food of India, providing 43 per cent of calorie requirement for more than 70 per cent of Indian population (Shetty *et al.*, 2013). To meet the demands of ever increasing population and maintain this self-sufficiency, the present production level, needs to be enhanced up to 122 million tonnes by the year 2020 (Anonymous, 2010). This certainly appears to be a massive venture, with the available technological options (Ahmed *et al.*, 2003). However, hybrid rice holds great promise to increase the rice production as it possess 10 to 15 per cent yield advantage over other varieties (Yang *et al.,* 1999). This high productivity of hybrid rice cannot be sustained on the partially reclaimed salt affected soils of Uttar Pradesh unless the declining trend in soil fertility resulting from the huge nutrient removal by hybrid rice is replenished properly (Singh, 2013). Adequate nutrient supply at critical growth stages are prerequisite to achieve optimum level of productivity and long term sustainability.Use of inorganic fertilizer alone is adversely affecting the soil productivity (Sutaria *et al.,* 2011) whereas conjunctive use of fertilizers and organic sources of nutrients improves the soil physical conditions *viz*. soil structure, aggregate stability, soil moisture retentivity and hydraulic conductivity as well as chemical properties of soil such as decreases soil pH, ESP, increase CEC *etc.* such improvement in soil physical and chemical conditions contribute to soil fertility and productivity (Hegde, 1998). At the current levels of inherent fertility Indian soil can sustain a production of about 87 million tonnes, and additional production could be achieved only through the development of best nutrient management modules with inclusion of locally available resource such as FYM, pressmud, water hyacinth, green manures and BGA *etc.* The use of local bio-degradable, non-toxic and cost effective agro waste can be well affordable for the Indian agrarian (Ashok *et al.*, 2015). The present study investigated the effect of various nutrient management modules on the yield of hybrid rice and availability of nutrients and soil properties.

MATERIALS AND METHODS

The research study "Effect of nutrient management modules on yield of hybrid rice and nutrient availability of alluvial soil at various growth stages of rice" was conducted at the Instructional Farm of Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P.) during *kharif* 2004-05 and 2005-06. The experimental site falls under subtropical zone in Indo-Gangetic plains having alluvial soil and lies between latitude 26.47°north and at longitude 82.12° east with elevation of about 113 m from mean sea level. Before laying out the experiment, a composite soil sample from 0-15 cm depth representing the whole field was collected and analyzed to know the physical and chemical properties of the soil. The results of initial analysis of soil have been presented in Table 1. The rice hybrid variety RPH-2 (Tata Rallies hybrid rice) was taken as test crop. The experiment was laid out in Randomized Block Design with three replications. One ploughing was done by tractor drawn soil turning plough followed by subsequent harrowing. The planking was done invariably after each harrowing. The field was divided into plots of 5 m x 4 m. All the 18 treatments to the plots were allotted randomly. FYM and pressmud was incorporated uniformly in the respective plots 7 days before transplanting of rice to the depth of 10-15 cm. Water hyacinth was applied in the field 15 days before transplanting of the rice. The water hyacinth was uniformly mixed in the soil. The treated plots were left for 15 days in order to facilitate the decomposition of water hyacinth. The species of Dhaincha (*Sesbania aculeata*) was collected from the outside field where it was already grown. The Dhaincha green manure crop was cut down after chopping with the help of sickle and it was incorporated in the field according to treatment in to the top 15 cm soil one week before transplanting. BGA crust as per treatment was incorporated uniformly in the plots 20 days after transplanting of rice crop. Full dose of P and K and half dose of N were applied as basal as per treatment while remaining half dose of N was applied in two equal splits at tillering and panicle initiation stages. A common dose of zinc sulphate was applied @ 25 kg ha^{-1}at the time of transplanting. Before transplanting of rice, plots were flooded with water and puddled. Transplanting was done manually at 20 cm x 15 cm distance using one seedling per hill. A thin film of water (2-3 cm) was maintained during the initial stage of seedling establishment. Thereafter, crop was irrigated as and when required to maintain the water level. Weeds were removed manually at 20 and 40 days after transplanting. The crop was harvested manually with the help of sickle when more than 90 per cent of the grains in the panicle were fully ripped and free from greenish tint. After taking the bundles weight of the harvested produce of each net plot, their grains were separated manually. The produce was then dried in the sun so as to obtain uniform moisture in the grains. The grain yield was recorded at 14 per cent moisture from each net plot after threshing and the values were converted to q ha^{-1}. Straw yield was recorded by subtracting the weight of grains from the weight of total harvested produce of each net plot. Soil samples were collected from 0-15 cm depth from each plot at tillering, panicle initiation and harvest stage of rice crop in both years. The soil samples were then air dried in the shade, grounded and sieved. Soil pH was measured with the help of pH meter using glass electrode in 1:2.5 soil water suspension as stated by Jackson (1973). EC of soil was determined by Conductivity Bridge using 1:2.5 soil water suspensions. Organic carbon of soil was determined by Walkley and Black's rapid titration method as discussed by Jackson (1973). Mechanical analysis was done by Bouyoucos hydrometer method as described by Kanwar and Chopra (1976). Available nitrogen content in soil samples was estimated by alkaline permanganate method as described by Subbiah and Asiza (1956). Available phosphorus was extracted by 0.5 M $NaHCO_3$ (pH 8.5) as per procedure of Olsen's and determined colorimetrically by molybdo-phosphoric blue colour method as described by Jackson (1973). Available K was determined flame photo-metrically by using neutral normal ammonium acetate solution as described by Jackson (1973). The available S content in soil was determined by *Turbidimeteric* method given by Williams and Steinbergs (1959). Zn content in soil was analyzed by DTPA (Diethylene triamine panta-acetic acid) extract method (Lindsay and Norwell, 1978). The experimental data were analyzed using "Analysis of variance technique" in randomized block design (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

Grain and straw yield

Grain and straw yield of rice (Table 2) was significantly influenced by various nutrient management modules. Maximum grain yield (70.15 and 67.12 q ha^{-1}) of rice crop was recorded under nutrient management module of 100% NPK + 5 t pressmud closely followed by 100% NPK + 10 t FYM. Significantly higher grain and straw yield was recorded under treatment having 100% NPK + 5 t pressmud over all the treatment except treatment T_1, T_2, T_4, T_5 and T_6 which was recorded at par. Twenty five percent reductions in recommended dose of NPK reduce the grain yield by 19.39% and 18.78% during first and second year, respectively. Application of 100% NPK with 10 t FYM and 100% NPK with 5 t pressmud significantly increased the grain yield by 20.86%, 23.68% and 23.25%, 26.05% during respective years over 100% NPK alone. Among the various nutrient management modules application of 5 t pressmud ha^{-1} found to be most superior at 100% NPK, 75% NPK as well as 50% NPK levels considering the grain yield of hybrid rice. The increase in grain and straw yield under treatment in question may be due to improved yield attributes and better translocation of photosynthates from source to sink. These results corroborates with the findings of (Singh 2005; Srivastava and Singh, 2016). Similarly, Alagappan and Venkitaswamy (2015) reported that INM imposed treatment performed better for grain yield of rice.

Soil pH, EC and organic carbon at harvest stage of rice crop

The maximum reduction in pH (8.00 and 8.05) 2004 and EC (0.26 and 0.25 dSm^{-1}) 2005 of soil was observed under treatment T_3 and T_2 supplied 100% NPK + 5 t pressmud and 100% NPK + 10 t FYM, respectively (Table 3). Higher reduction in pH and EC was noticed in treatment having pressmud followed by FYM. However, differences among various treatments were not up to the level of significance. The reduction in EC of the soil with FYM and pressmud may ascribed to salt leaching facilitated by improved permeability

Table 1: Initial physico-chemical properties of the soil of experimental site

Soil Properties	2004	2005
Texture	Silt loam	
pH (1:2.5)	8.50	8.40
EC (dSm^{-1} at 25°C)	0.40	0.38
Organic Carbon (%)	0.39	0.38
Available N (kg ha^{-1})	165	154
Extractable P (kg ha^{-1})	11.40	10.55
Extractable K (kg ha^{-1})	266.0	250.0
Available S (kg ha^{-1})	13.80	12.68
Available Zn (ppm)	0.42	0.40

Table 2: Effect of various nutrient management modules on grain and straw yield

Treatments	Grain yield (q ha^{-1})		Straw yield (q ha^{-1})	
	2004	2005	2004	2005
T_1 = 100% NPK (150:75:75 NPK kg ha^{-1})	56.72	53.25	70.90	67.12
T_2 = 100% NPK + 10 t FYM ha^{-1}	68.55	65.63	85.00	82.03
T_3 = 100% NPK + 5 t pressmud ha^{-1}	70.15	67.12	86.28	82.55
T_4 = 100% NPK + 5 t water hyacinth ha^{-1}	62.85	59.46	78.99	74.34
T_5 = 100% NPK + 5 t Sesbania (GM) ha^{-1}	63.00	60.70	79.54	76.51
T_6 = 100% NPK + 10 kg BGA crust ha^{-1}	61.80	58.70	77.80	73.99
T_7 = 75% NPK (112.5:56.25:56.25 NPK kg ha^{-1})	42.50	40.00	53.97	51.20
T_8 = 75% NPK + 10 t FYM ha^{-1}	55.55	53.85	69.99	68.38
T_9 = 75% NPK + 5 t pressmud ha^{-1}	56.32	54.46	70.40	68.61
T_{10} = 75% NPK + 5 t water hyacinth ha^{-1}	53.90	52.00	68.99	67.08
T_{11} = 75% NPK + 5 t Sesbania (GM) ha^{-1}	54.58	52.80	68.77	67.05
T_{12} = 75% NPK + 10 kg BGA crust ha^{-1}	53.10	51.35	67.43	65.72
T_{13} = 50% NPK (75: 37.5:37.5 NPK kg ha^{-1})	30.25	27.10	40.53	36.58
T_{14} = 50% NPK + 10 t FYM ha^{-1}	43.55	40.65	57.05	53.65
T_{15} = 50% NPK + 5 t pressmud ha^{-1}	44.80	41.80	58.24	54.75
T_{16} = 50% NPK + 5 t water hyacinth ha^{-1}	41.85	39.70	55.24	52.80
T_{17} = 50% NPK + 5 t Sesbania (GM) ha^{-1}	42.70	40.20	56.79	53.86
T_{18} = 50% NPK + 10 kg BGA crust ha^{-1}	41.00	38.65	54.94	52.17
SEm ±	3.56	3.61	4.00	4.22
C.D. (P=0.05)	10.25	10.41	11.53	12.15

Table 3: pH, EC and organic carbon content in soil under influence of various nutrient management modules

Treatments	pH		EC (dSm^{-1})		Organic carbon (%)	
	2004	2005	2004	2005	2004	2005
T_1 = 100% NPK (150:75:75 NPK kg ha^{-1})	8.20	8.10	0.30	0.29	0.42	0.40
T_2 = 100% NPK + 10 t FYM ha^{-1}	8.05	7.86	0.27	0.26	0.53	0.51
T_3 = 100% NPK + 5 t pressmud ha^{-1}	8.00	7.85	0.26	0.25	0.54	0.52
T_4 = 100% NPK + 5 t water hyacinth ha^{-1}	8.06	7.88	0.28	0.27	0.47	0.45
T_5 = 100% NPK + 5 t Sesbania (GM) ha^{-1}	8.07	7.88	0.28	0.27	0.48	0.45
T_6 = 100% NPK + 10 kg BGA crust ha^{-1}	8.10	7.90	0.29	0.28	0.47	0.46
T_7 = 75% NPK (112.5:56.25:56.25 NPK kg ha^{-1})	8.35	8.20	0.35	0.33	0.40	0.38
T_8 = 75% NPK + 10 t FYM ha^{-1}	8.21	8.15	0.31	0.29	0.48	0.46
T_9 = 75% NPK + 5 t pressmud ha^{-1}	8.20	8.12	0.30	0.28	0.48	0.46
T_{10} = 75% NPK + 5 t water hyacinth ha^{-1}	8.22	8.16	0.33	0.31	0.45	0.43
T_{11} = 75% NPK + 5 t Sesbania (GM) ha^{-1}	8.22	8.16	0.32	0.31	0.46	0.42
T_{12} = 75% NPK + 10 kg BGA crust ha^{-1}	8.23	8.17	0.34	0.32	0.44	0.42
T_{13} = 50% NPK (75: 37.5:37.5 NPK kg ha^{-1})	8.40	8.32	0.38	0.37	0.39	0.37
T_{14} = 50% NPK + 10 t FYM ha^{-1}	8.35	8.26	0.34	0.33	0.47	0.45
T_{15} = 50% NPK + 5 t pressmud ha^{-1}	8.30	8.25	0.33	0.33	0.48	0.46
T_{16} = 50% NPK + 5 t water hyacinth ha^{-1}	8.37	8.28	0.36	0.35	0.44	0.42
T_{17} = 50% NPK + 5 t Sesbania (GM) ha^{-1}	8.36	8.27	0.36	0.35	0.45	0.43
T_{18} = 50% NPK + 10 kg BGA crust ha^{-1}	8.37	8.28	0.37	0.36	0.42	0.41
SEm ±	0.12	0.13	0.02	0.02	0.02	0.02
C.D. (P=0.05)	NS	NS	NS	NS	0.07	0.07

of soil and to the formation of weak salts as a results of reaction between weak organic acids formed during further decomposition of FYM and the soluble cations present in the soil. These results closely corroborates with the findings of Sekhon and Bajwa (1993), Dubey and Verma (1999), Kumar *et al.* (2001), Kumar (2002) and Singh (2005). Build up in organic carbon content of soil over its initial stage increased significantly in all the treatments having FYM and pressmud along with 50%, 75% and 100% NPK over alone application of NPK. Highest organic carbon (0.54 % and 0.52%) content was estimated under treatment having 100% NPK + 5 t pressmud which were significantly superior over all the treatments except treatments T_2, T_4, T_5, T_6, T_8 and T_9 (Table 3). The significant improvement in organic carbon content of soil with treatments consisting 100%, 75% and 50% NPK along with FYM and pressmud may be ascribed due to additive effect of organic carbon through FYM and pressmud. Yadav and Kumar (2009) reported that soil organic matter is known to serve as soil conditioners, nutrient resource, substrate for microbial activity, preserver of environment and major determinant for sustaining agricultural productivity. Similarly, Nayak *et al*. (2015) recorded highest organic carbon with 100% NPK + FYM followed by 150% NPK.

Nutrients availability at various growth stages

Available nitrogen

Available N in soil at tillering stage (TS), panicle initiation (PI) and harvest stage (HS) was significantly influenced by FYM,

Table 4: Available S (kg ha^{-1}) in soil at various growth stages of rice under influence of various nutrient management modules

Treatments	Tillering stage		Panicle initiation		At harvest	
	2004	2005	2004	2005	2004	2005
T_1 = 100% NPK (150:75:75 NPK kg ha^{-1})	13.75	12.60	12.16	11.20	11.40	9.50
T_2 = 100% NPK + 10 t FYM ha^{-1}	14.78	13.67	13.45	12.50	12.10	11.25
T_3 = 100% NPK + 5 t pressmud ha^{-1}	14.85	13.78	13.60	12.54	12.20	11.32
T_4 = 100% NPK + 5 t water hyacinth ha^{-1}	13.90	12.85	12.80	11.75	10.70	9.65
T_5 = 100% NPK + 5 t Sesbania (GM) ha^{-1}	13.95	12.90	12.95	11.85	10.87	9.72
T_6 = 100% NPK + 10 kg BGA crust ha^{-1}	13.80	12.85	12.60	11.55	10.49	9.52
T_7 = 75% NPK (112.5:56.25:56.25 NPK kg ha^{-1})	13.60	12.55	12.05	11.10	10.20	9.12
T_8 = 75% NPK + 10 t FYM ha^{-1}	14.75	13.68	13.28	12.30	12.00	11.10
T_9 = 75% NPK + 5 t pressmud ha^{-1}	14.86	13.77	13.44	12.48	12.12	11.25
T_{10} = 75% NPK + 5 t water hyacinth ha^{-1}	13.75	12.70	12.60	11.55	10.55	9.65
T_{11} = 75% NPK + 5 t Sesbania (GM) ha^{-1}	13.95	12.82	12.85	11.70	10.66	9.72
T_{12} = 75% NPK + 10 kg BGA crust ha^{-1}	13.65	12.50	12.45	11.50	10.40	9.40
T_{13} = 50% NPK (75: 37.5:37.5 NPK kg ha^{-1})	13.25	12.40	12.00	11.02	10.05	9.00
T_{14} = 50% NPK + 10 t FYM ha^{-1}	14.36	13.45	13.17	12.26	11.85	10.80
T_{15} = 50% NPK + 5 t pressmud ha^{-1}	14.44	13.56	13.32	12.40	11.94	10.94
T_{16} = 50% NPK + 5 t water hyacinth ha^{-1}	13.34	12.48	12.55	11.60	10.44	9.50
T_{17} = 50% NPK + 5 t Sesbania (GM) ha^{-1}	13.42	12.54	12.80	11.82	10.54	9.66
T_{18} = 50% NPK + 10 kg BGA crust ha^{-1}	13.30	12.44	12.34	11.52	10.32	9.40
SEm ±	1.00	1.02	1.16	1.10	1.35	1.25
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS

Table 5: Available Zn (ppm) in soil at various growth stages of rice under influence of various nutrient management modules

Treatments	Tillering stage		Panicle initiation		At harvest	
	2004	2005	2004	2005	2004	2005
T_1 = 100% NPK (150:75:75 NPK kg ha^{-1})	0.46	0.44	0.42	0.41	0.38	0.36
T_2 = 100% NPK + 10 t FYM ha^{-1}	0.56	0.56	0.48	0.46	0.46	0.44
T_3 = 100% NPK + 5 t pressmud ha^{-1}	0.57	0.57	0.49	0.47	0.47	0.45
T_4 = 100% NPK + 5 t water hyacinth ha^{-1}	0.50	0.48	0.45	0.45	0.43	0.42
T_5 = 100% NPK + 5 t Sesbania (GM) ha^{-1}	0.51	0.49	0.46	0.46	0.44	0.43
T_6 = 100% NPK + 10 kg BGA crust ha^{-1}	0.49	0.47	0.45	0.44	0.42	0.40
T_7 = 75% NPK (112.5:56.25:56.25 NPK kg ha^{-1})	0.42	0.40	0.41	0.39	0.35	0.33
T_8 = 75% NPK + 10 t FYM ha^{-1}	0.51	0.51	0.46	0.44	0.43	0.41
T_9 = 75% NPK + 5 t pressmud ha^{-1}	0.52	0.52	0.47	0.45	0.44	0.42
T_{10} = 75% NPK + 5 t water hyacinth ha^{-1}	0.44	0.47	0.42	0.40	0.36	0.33
T_{11} = 75% NPK + 5 t Sesbania (GM) ha^{-1}	0.45	0.48	0.43	0.41	0.37	0.34
T_{12} = 75% NPK + 10 kg BGA crust ha^{-1}	0.44	0.41	0.42	0.40	0.36	0.33
T_{13} = 50% NPK (75: 37.5:37.5 NPK kg ha^{-1})	0.39	0.38	0.38	0.37	0.31	0.30
T_{14} = 50% NPK + 10 t FYM ha^{-1}	0.49	0.50	0.45	0.43	0.40	0.39
T_{15} = 50% NPK + 5 t pressmud ha^{-1}	0.50	0.51	0.46	0.44	0.41	0.40
T_{16} = 50% NPK + 5 t water hyacinth ha^{-1}	0.43	0.42	0.40	0.38	0.33	0.34
T_{17} = 50% NPK + 5 t Sesbania (GM) ha^{-1}	0.44	0.46	0.41	0.40	0.36	0.36
T_{18} = 50% NPK + 10 kg BGA crust ha^{-1}	0.41	0.40	0.38	0.37	0.32	0.33
SEm ±	0.03	0.04	0.02	0.02	0.03	0.03
C.D. (P=0.05)	0.09	0.11	0.05	0.05	0.08	0.08

pressmud, water hyacinth, green manure and BGA along with 50%, 75% and 100% NPK over 50%, 75% and 100% NPK alone, respectively (Fig.1 & 2). The availability of N was reduces towards maturity stages. Maximum N availability at TS (228.2 kg ha^{-1}), PI (203.5 kg ha^{-1}) and HS (185.9 kg ha^{-1}) was estimated under treatment T_3 (100% NPK + 5 t pressmud), while minimum 170.47 kg ha^{-1} (at TS), 140.5 kg ha^{-1} (at PI) and 124.8 kg ha^{-1} (at HS) in treatment T_{13} (50% NPK alone) during 2004. Same trend was observed during 2005. Considerable improvement in available N content of soil was observed under all treatments over T_{13}. Application of FYM, pressmud, water hyacinth, green manure and BGA along with different recommended dose of NPK significantly increased available N in soil over NPK alone treatments. N increment might be due to release of extracellular N substances and fixation of atmospheric N. Available N in soil increased with the combination of chemical fertilizers and GM because of buildup of organic matter (Singh, 2014). Similar, findings were also observed by Sharma and Ghosh (2000).

Available phosphorus

Maximum P availability at TS (17.15 and 16.66 kg ha^{-1}), PI (16.3 and 15.10 kg ha^{-1}) and HS (14.20 and 13.71 kg ha^{-1}) was computed under treatment T_3 (100% NPK + 5 t pressmud), while minimum at all stages was recorded in T_{13} plots during both the years (Fig.3 and 4). Available phosphorus content in soil at all stage under treatment T_{14}, T_{15}, T_{16}, T_{17} and T_{18} estimated significantly superior over treatment T_{13} and at par with treatment T_7. Increased availability of P in soil under

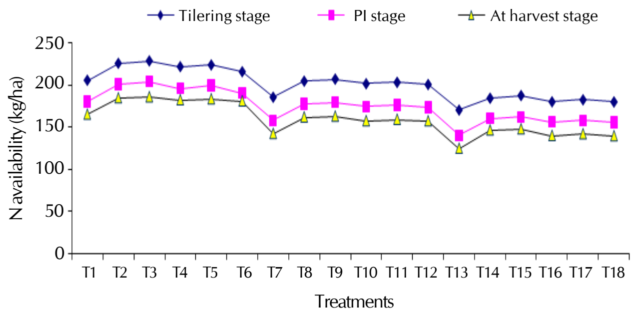

Figure 1: Effect of nutrient management modules on N availability during 2004

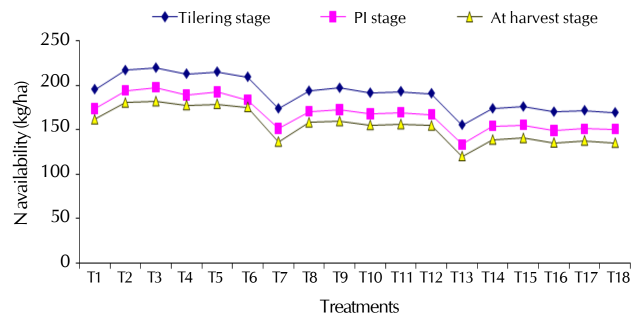

Figure 2: Effect of nutrient management modules on N availability during 2005

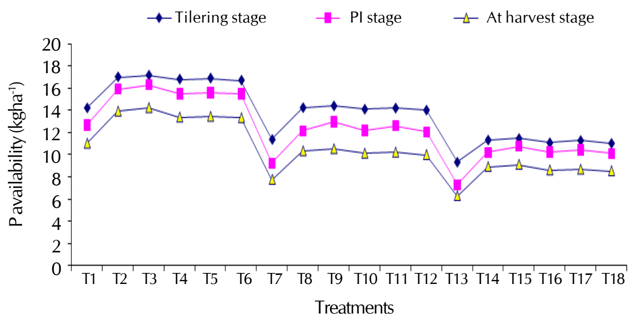

Figure 3: Effect of nutrient management modules on P availability during 2004

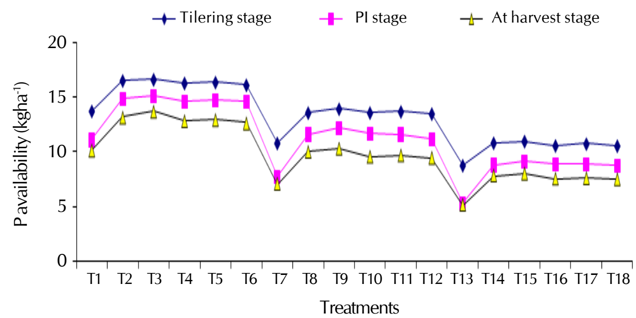

Figure4: Effect of nutrient management modules on P availability during 2005

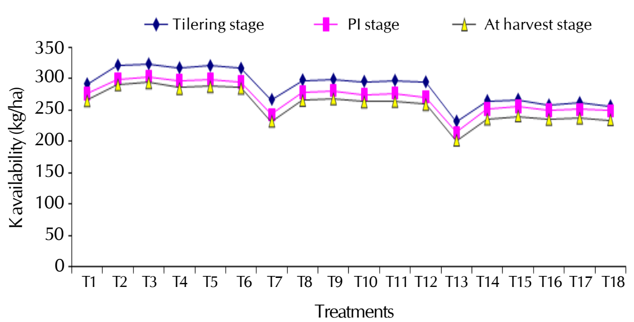

Figure 5: Effect of nutrient management modules on K availability during 2004

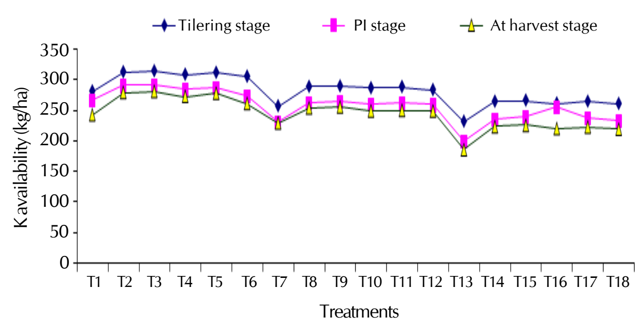

Figure 6: Effect of nutrient management modules onK availability during 2005

integrated use of chemical fertilizers and green manure plots might be increased solubility due to production of organic acids (Singh, 2014). Similar findings were also observed by Kumar (2002) and Singh (2005).

Available potassium

Significant improvement was recorded in K availability at all the growth stages by application of pressmud, FYM, water hyacinth, green manure and BGA along with inorganic levels (100%, 75% and 50% NPK) of fertilizer over alone levels of inorganic fertilizers (100%, 75% and 50% NPK), respectively (Fig.5 and 6). Maximum K availability at TS (324.60 and 315.30 kg ha^{-1}), PI (303.4 and 291.6 kg ha^{-1}) and HS (294.5 and 282.3 kg ha^{-1}) was recorded in soil under treatment having 100% NPK + 5 t pressmud which was significantly superior over all the treatments except treatments T_2, T_4, T_5 and T_6 which was at par at all the growth stages of crop. It might be due to direct addition of K to the available pool of the soil and interaction of organic manure with clay which minimizes fixation and improved release of K (Singh *et al.*, 2011). Similarly, Anand *et al*. (2000) observed a marginal improvement in K status with 100and 150% NPK treatments.

Available sulphur

All the treatments were at par in respect to S availability in soil at all the growth stages of crop, although a slight increase was noticed under treatment having FYM and pressmud. Maximum S availability in soil at all the growth stages was recorded under treatment having 100% NPK + 5 t pressmud (Table 4). Availability of S increased significantly with combined application of organic and inorganic sources of nutrients (Bellakki *et al*., 1998 and Kumar, 2002).

Available zinc

Maximum Zn availability (0.57 and 0.57 ppm) at TS, (0.49

and 0.47 ppm) at PI and (0.47 and 0.45 ppm) at HS was estimated under treatment T_3 (Table 5). Application of FYM and pressmud along with 100% NPK, 75% NPK and 50% NPK increased available Zn in soil over 100% NPK, 75% NPK and 50% NPK alone treatment respectively. Increased in availability of Zn in soil may be ascribed due to the additive supply of Zn through FYM, PM and zinc sulphate fertilizer which increased the availability of Zn under treatment having PM and FYM along with inorganic fertilizer. Similarly, Singh (2014) recorded highest available Zn (0.48 and 0.50 ppm) in plot receiving 75% RDF + GM. Similar findings were also observed by (Kumar and Yadav, 1995; and Kumar, 2002).

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