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Productivity of short-duration summer forage crops and their effect on succeeding aromatic rice in conjunction with gypsum-enriched urea

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ABSTRACT

Field experiments were conducted during 2006 and 2007 at New Delhi to study the productivity of summer forage crops and their effect in conjunction with gypsum-enriched urea (GEU) *viz.,* absolute control, 0, 5, 10 and 15% on aromatic rice and economics of summer forage-aromatic rice cropping system. Among the 3 forage crops, maize + cowpea mixture recorded significantly higher dry fodder yields (13.18 t/ha) than sole cowpea (10.98 t/ha). Significantly the higher grain yield (2 year mean of 5.86 tonne/ha) and N, P, K and S uptake of aromatic rice was recorded when it was grown after cowpea than other treatments. Significantly higher grain (6.19 t/ha), and biological yields were recorded with 10% GEU. Significantly higher nutrient (NPKS) uptake was recoded with 15% GEU when compared with lower levels of GEU. Significantly higher net returns were recorded in forage maize + cowpea mixture-aromatic rice cropping system and with 15% GEU.

***Key words*: Economics, Gypsum, Nutrient uptake, Rice, Urea, Yield**

Rice (*Oryza sativa* L.) is the premier food crop of India and its food security largely depends on the production and productivity of rice ecosystem. Among the rice growing countries, India stands first in area (43.7 million ha) and second in production (91.8 million tonnes) next only to China. However, the average productivity of rice in India is only 2.10 tonnes/ha against the world average of 2.75 tonnes/ha (FAI, 2006-07). Globally, the United Nations General Assembly on 16 December, 2002 declared 2004 as the International Year of Rice (IYR). The theme of IYR, "Rice is life, and was drawn from the understanding that rice-based systems are essential to every one, directly or indirectly, for food security, poverty alleviation and global peace. The productivity and quality of aromatic rice depends on environmental conditions and the agronomic management practices of that area (Oo *et al*., 2007). Nitrogen is considered as the quality and quantity limiting factors for paddy. The influence of N was more pronounced as compared to sulphur and both these nutrients had interacted significantly in increasing the grain yields (Oo *et al.,* 2007). In northern India many farmers after harvesting of wheat grow short-duration summer forage crops to feed their animals before transplanting of aromatic rice. During extreme summer (May-June) there is scarcity of green fodder because of non-availability of green berseem and sugarcane tops, which are the major fodder crops in northern India during *rabi*. Therefore, the farmers generally grow short-duration summer forage crops like cowpea, maize or mixture with cowpea. So far no scientific studies and their documentation have been done on this aspect.

Low N use efficiency (NUE) in rice is a matter of great concern to the farmers as well as researchers. It generally varies from 30–50 % under lowland situations depending on the climatic, edaphic and management factors. Worldwide NUE for cereal crops is about 33% (Ladha *et al.,* 2005). The main routes of N loss in rice paddies are volatilization, denitrification and leaching. The slow release or controlled release fertilizers are mainly used to reduce leaching of nutrients, especially nitrate-N to groundwater, caused due to by application of soluble N fertilizers to sandy or sandy loam soils (Sato and Morgan, 2008). The low NUE has several economic, social and environmental consequences. Therefore, considering the above mentioned facts in view a field experiment was undertaken to study the effect of preceding summer forage crops and gypsum enriched urea (GEU) applied to rice in summer forage–aromatic rice cropping system.

MATERIALS AND METHODS

Field experiments were carried out during summer and *kharif* (April-October) of 2006 and 2007 at the research farm of the Indian Agricultural Research Institute, New Delhi. The soil of the experimental site was sandy clay loam (51.80% sand, 22.20% silt and 26.40% clay) having

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pH 8.1, organic carbon content 0.52%, and 132.6-16.2-278.3-11.4 kg/ha of available N-P-K-S in the plough layer. The summer forage crops *viz.,* maize 'African tall' and cowpea 'V 585' were sown in April received 2 irrigations during both the years. After harvest of forage crops, soil samples were drawn from the plough soil layer to analyze the soil for organic carbon (%), available N, P, K, S (kg/ha) (Table 1). The rice field experiments were carried out in split plot design with 3 replications having 4 summer forage crops *viz.,* maize, cowpea, maize + cowpea mixture and fallow which were assigned to the main plot and 5 GEU level *viz.,* absolute control, 0, 5, 10 and 15% to the sub-plots.

Twenty five day-old seedlings of aromatic fine rice 'Pusa Sugandh 4' were transplanted at 20 cm x 10 cm spacing keeping 2 seedlings/hill. Nitrogen @ 120 kg/ha was uniformly applied in all GEU treatments. Quantity of GEU was decided based on the N content in the respective GEU fertilizer materials. The GEU was applied in 2 equal split: ½ each at the transplanting and active tillering stages, respectively. Throughout the growing season the crop was kept in 5–6 cm standing water. The concentrations of various nutrients in plant and soil were estimated by standard methods. Economis were also calculated as per the prevailing market prices of the inputs and produce.

RESULTS AND DISCUSSION

Fodder yield

Among the 3 summer forage crops, maize + cowpea mixture recorded significantly higher fodder yields as compared to their sole crops during both the years of experimentation. The green fodder yield of maize + cowpea mixture was 15.5 and 44.6% higher than sole maize and sole cowpea, respectively during 2006 (Table 2). Almost similar trend was recorded during 2007. In general, less fodder yield was recorded during 2007 when compared with in 2006 owing to harsh weather conditions during 2007.

Aromatic rice

Yield attributes

Preceding summer forage crops had significant effect on panicles/hill during both the years and panicle length of rice during 2007 only. Significantly higher number of panicles were recorded when rice was grown after forage cowpea when compared with the other summer treatments in both the years. The panicle length of rice grown after the harvest forage maize/cowpea was significantly more than that after maize + cowpea mixture and fallow. The highest values of number of grains/panicle and grain weight (g)/panicle were recoded when rice was grown after forage cowpea (Table 3). This can be attributed to the more residual effect of biological N fixed by the cowpea.

GEU showed significant effect on all the yield attributing characters except 1,000-grain weight of rice (Table 3). Application of 10% GEU recorded significantly higher panicles/hill, panicle length, number of grains/panicle, grains weight/panicle over absolute control and 0% GEU but remained statistically on par with 5 and 15% GEU during both the years. However, the highest values of all these yield attributes were recorded with 15% GEU. The slow release of N for longer period played a pivotal role in increasing the yield attributes with successive increase in GEU level. Shivay *et al.* (2001) Shivay (2007) also reported significant increase in the yield attributes of rice irrespective of the modified sources of N.

Yield

The preceding summer forage crops had significant effect on grain, biological yields and harvest index of rice during both the years of study (Table 4). Significantly higher grain, biological yields and harvest index of rice were recorded when it was grown after forage cowpea than rest of the summer forage crops as well as fallow. The mean grain yield of rice grown after forage cowpea was

Table 2. Green and dry forage yields of summer forage crops

Treatment	Green (dry) forage yield (t/ha)	
	2006	2007
Sole maize	36.42 (12.67)*	35.94 (12.02)
Sole cowpea	29.12 (9.98)	28.59 (11.80)
Maize + cowpea mixture	42.10 (14.06)	41.38 (12.30)
SEm±	0.35 (0.41)	0.36 (0.40)
CD (P=0.05)	1.40 (1.63)	1.43 (1.72)

Table 1. Organic carbon (OC) content (%) and available nutrients (kg/ha) in soil after harvest of summer forage crops

Treatment	OC		N		P		K		S	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Sole maize	0.54	0.54	127.8	124.9	16.3	14.5	271.5	265.3	11.5	11.2
Sole cowpea	0.56	0.56	175.6	171.8	16.9	15.1	289.0	284.0	12.5	12.6
Maize + cowpea mixture	0.55	0.56	163.6	158.4	16.6	14.6	276.4	270.4	11.8	12.1
Fallow	0.52	0.52	132.6	128.3	16.2	14.1	278.3	272.0	11.4	11.5
SEm±	0.01	0.01	2.1	2.0	0.7	0.5	2.7	2.8	0.7	0.7
CD (P=0.05)	0.02	0.02	7.2	7.0	NS	NS	9.3	9.8	NS	NS

9.5, 3.7 and 8.2% higher over that after maize, maize+cowpea mixture and fallow, respectively (Table 4). Almost similar trends were also recorded with biological yield. This might be due to more residual effect of biological N-fixed in the root nodules of previous crop of cowpea.

GEU showed significant influence on grain, biological yields and harvest index of aromatic rice. Application of 10% GEU recorded significantly higher grain, biological yields and harvest index over absolute control, 0 and 5% GEU during 2006. However, during 2007, 5% GEU recorded significantly higher grain yield over absolute control and 0% GEU. The grain yield of aromatic rice at 15% GEU on an average was in 53.3, 19.6 and 5.9, and 1.9% higher over control, 0, 5 and 10% GEU respectively (Table 4). The biological yield of rice at 15% GEU was 34.9, 14.2 5.4 and 2.0% higher over absolute control, 0, 5 and 10% GEU, respectively. The controlled release of N and longer supply of mineralized N to the plants (Shivay *et al*., 2001; Bharde *et al*., 2003 and Shivay, 2007) might have led to increased photosynthetic activity and finally increased grain yield and biological yield. Significantly higher harvest index of rice was recorded with 5% GEU when compared with absolute control and 0% GEU. The harvest index is mainly controlled by partition of photosynthates between harvesting and non-harvesting organs during the crop growth cycle. The variation in partitioning of photosynthates in grain and vegetative organs of differ-

Table 3. Effect of preceding summer forage crops and GEU on yield attributes of aromatic rice

Treatment	Panicles/m^2		Panicle length (cm)		Grains/panicle		Grains weight (g)/panicle		1,000-grain weight	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Summer forage crop										
Sole maize	555	525	27.3	25.3	69.7	66.2	1.80	1.76	25.65	24.65
Sole cowpea	625	600	27.1	25.4	69.4	66.4	1.80	1.76	25.46	24.46
Maize + cowpea mixture	590	565	26.8	24.7	67.9	64.8	1.77	1.72	25.45	24.45
Fallow	520	495	27.3	24.1	70.9	67.3	1.77	1.73	25.51	24.02
SEm±	0.5	3	0.3	0.2	1.1	1.1	0.03	0.02	0.53	0.53
CD (P=0.05)	1.0	9	0.9	0.6	NS	NS	NS	NS	NS	NS
Gypsum-enriched urea (GEU)										
Control	410	385	25.0	22.8	64.1	61.0	1.63	1.59	24.49	23.37
0% GEU	530	505	26.6	24.4	67.7	64.4	1.72	1.68	25.11	23.99
5% GEU	580	555	27.3	25.2	69.7	66.1	1.79	1.75	25.70	24.58
10% GEU	650	625	28.0	25.8	72.4	68.8	1.87	1.83	25.82	24.69
15% GEU	690	655	28.5	26.3	73.6	70.5	1.92	1.88	26.48	25.36
SEm ±	2.5	3	0.3	0.3	1.1	1.0	0.03	0.02	0.57	0.57
CD (P=0.05)	7.5	8	1.0	0.9	3.2	3.0	0.09	0.07	NS	NS

Table 4. Effect of preceding summer forage crops and GEU on grain, biological yields (t/ha), harvest index and mean economics (Rs/ha) of aromatic rice

Treatment	Grain yield		Biological yield		Harvest index		Cost of cultivation	Net returns	Benefit : cost ratio
	2006	2007	2006	2007	2006	2007			
Summer forage crop									
Sole maize	5.41	5.29	18.36	17.89	29.1	29.7	29,701	67,125	2.23
Sole cowpea	5.92	5.80	19.70	19.12	29.9	30.0	31,222	60,996	1.93
Maize + cowpea mixture	5.71	5.59	19.20	18.44	29.5	30.0	30,359	76,097	2.48
Fallow	5.54	5.29	18.74	17.92	29.4	29.1	24,307	28,784	0.98
SEm±	0.05	0.04	0.11	0.11	0.2	0.2		553	0.02
CD (P=0.05)	0.19	0.15	0.37	0.37	0.7	0.7		1,913	0.06
Gypsum-enriched urea (GEU)									
Control	4.21	4.02	15.80	15.04	26.6	26.7	27,551	46,812	1.59
0% GEU	5.34	5.21	18.22	17.65	29.3	29.4	28,848	55,667	1.82
5% GEU	6.03	5.88	19.77	19.11	30.4	30.6	28,909	61,496	2.00
10% GEU	6.27	6.11	20.43	19.73	30.5	30.7	30,306	62,495	2.03
15% GEU	6.38	6.23	20.78	20.18	30.6	30.8	28,872	64,785	2.10
SEm±	0.06	0.08	0.17	0.21	0.3	0.3		654	0.02
CD (P=0.05)	0.19	0.24	0.48	0.62	0.8	0.7		1,889	0.06

ent treatments possibly caused a significant variation in harvest index. Similar results were reported by Singh and Shivay (2003).

Nutrient uptake

The preceding summer forage crops had significant effect on total (grain + straw) N, P, K and S uptake of rice during both the years (Table 5). The nutrient (NPKS) uptake by rice was significantly higher when it was grown after forage cowpea when compared with rest of the treatments during both the years of study. The N uptake of aromatic rice after forage cowpea on an average was 16.5, 4.8 and 14.4% higher over sole maize, maize + cowpea mixture and fallow, respectively. The increase in P uptake of rice grown after forage cowpea was 10.2, 4.0 and 15.7% over sole maize, maize + cowpea mixture and fallow respectively. The K uptake of rice followed the trend of N and P and in general, was slightly higher in first year when compared with the second year of the experiment. The S uptake in aromatic rice grown after forage cowpea was significantly superior to that after sole maize crop but was on par with maize + cowpea mixture and fallow treatment.

GEU had significant effect on nutrient uptake of rice. The maximum NPKS uptake was recorded with 15% GEU during both the years. The N uptake of rice with 15% GEU on an average was 71.4, 31.8, 13.0 and 6.2% higher over control, 0, 5 and 10% GEU, respectively (Table 5). Similarly, P uptake also increased significantly with each successive increase in the level of GEU up to 10% and this treatment remained statistically on par with 15% GEU. The K and S uptake of aromatic rice with 15% GEU on an average was 52.7, 27.3, 12.5, 5.4% and 119.8, 55.7, 21.5 and 6.9% higher over control, 0, 5 and 10% GEU, respectively. This might be due to increase in the GEU levels increased the grain and straw yields of rice and also N,P,K and S concentrations proportionately in grain and straw that finally lead to increased uptake. These results are in accordance with the findings of Oo *et al*. (2007) and Shivay (2007).

Soil fertility after aromatic rice

The preceding summer forage crops and level of GEU had significant effect on OC, available N,P,K and S status of soil after the harvest of rice crop. Significantly higher OC content and available NPKS was recorded when aromatic rice was grown after forage cowpea as compared to other treatments in both the years. However, the OC (2006) and available P and S (2007) after forage cowpea was statistically on par with maize + cowpea mixture treatment. The OC content and available NPKS of soil increased significantly with each successive increase in the level of GEU up to the highest level *i.e.* 15% GEU during both the years of study. GEU including prilled urea being at par with each other was significantly higher in sole cowpea and sole cowpea + maize – were statistically at par over control in both the years of experimentation. Significantly higher available NKS in soil after harvest of aromatic rice was recorded with 15% GEU in both the years. The OC content of soil in all levels of GEU including prilled urea being at par with each other was significantly higher over control during both the years. Each successive increase in GEU had slightly negative impact on available

Table 5. Effect of preceding summer forage crops and GEU on nutrient uptake of aromatic rice

Treatment	Nutrient uptake (kg/ha)							
	N		P		K		S	
	2006	2007	2006	2007	2006	2007	2006	2007
Summer forage crop								
Sole maize	141.2	132.6	22.58	21.35	231.3	220.6	18.83	19.00
Sole cowpea	164.4	154.4	24.79	23.62	229.9	218.8	22.02	21.90
Maize + cowpea mixture	157.0	147.4	23.90	22.66	215.9	203.0	21.21	21.40
Fallow	145.7	133.1	21.78	20.03	236.0	221.7	21.75	21.20
SEm±	2.0	0.8	0.23	0.25	4.9	1.5	0.39	0.38
CD (P=0.05)	6.8	2.8	0.80	0.85	16.9	5.1	1.01	1.24
Gypsum-enriched urea (GEU)								
Control	107.4	98.4	16.26	14.62	174.1	161.5	13.32	11.40
0%GEU	138.4	129.1	21.30	20.01	211.0	199.9	18.03	16.80
5%GEU	161.2	150.7	24.73	23.23	235.3	223.6	21.74	22.80
10%GEU	171.0	161.0	26.66	25.15	253.6	240.2	25.05	25.40
15%GEU	182.2	170.1	27.36	26.57	267.4	255.2	26.64	27.70
SEm±	2.1	1.9	0.29	0.40	4.9	2.5	0.45	0.36
CD (P=0.05)	6.0	5.7	0.84	1.16	14.1	7.3	1.31	0.83

Table 6. Effect of preceding summer forage crops and GEU on available nutrients (kg/ha) in soil after harvest of aromatic rice

Treatment	N		P		K		S		OC (%)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Summer forage crop										
Maize	126.1	121.9	15.3	14.5	272.6	263.7	11.5	11.4	0.54	0.54
Cowpea	136.2	132.2	16.0	15.1	287.7	276.0	12.5	12.6	0.56	0.56
Maize + Cowpea	130.9	126.7	15.6	14.6	278.4	268.7	11.9	12.1	0.56	0.55
Fallow	123.3	119.2	15.2	14.0	274.9	264.3	11.4	11.5	0.53	0.53
SEm±	0.6	0.4	0.1	0.2	2.1	1.0	0.1	0.2	0.003	0.001
CD (P=0.05)	2.1	1.5	0.4	0.7	7.4	3.5	0.4	0.6	0.009	0.005
Gypsum-enriched urea (GEU)										
Control	117.6	113.9	16.7	16.2	254.8	246.9	9.6	8.4	0.52	0.52
0% GEU	124.6	120.1	15.6	14.6	264.9	256.1	10.8	9.8	0.54	0.55
5% GEU	130.9	125.7	15.4	14.4	281.7	271.0	11.9	11.7	0.55	0.55
10% GEU	134.5	130.5	15.0	13.9	289.5	278.6	12.6	13.7	0.55	0.55
15% GEU	138.1	134.8	14.9	13.6	301.1	288.3	14.0	15.9	0.55	0.55
SEm±	1.0	0.8	0.3	0.3	3.0	1.6	0.3	0.4	0.003	0.003
CD (P=0.05)	2.9	2.3	1.0	0.9	8.7	4.6	0.9	1.0	0.009	0.009

P in soil after harvest of aromatic rice. Absolute control recorded significantly higher available P in soil after harvest of rice over all GEU treatments during both the years of study.

Economics

Significantly higher net returns and B:C ratio were recorded in maize + cowpea-aromatic rice cropping system when compared with other three treatments (Table 4). GEU had significant effect on net returns and B:C ratio. Application of 15% GEU increased net returns and B:C ratio significantly when compared with all other levels of GEU including control. Similar trend was recorded for B:C ratio with GEU. These results corroborate with Bharade *et al*. (2006) who also reported that with modified urea materials recorded significantly higher returns in rice–wheat cropping system.

Consequently among the 3 forage crops grown during summer, maize + cowpea mixture recorded significantly higher fodder productivity. The growing of aromatic rice after summer forage crops like sole cowpea or cowpea + maize mixture in conjunction with application of 10 or 15% gypsum-enriched urea (120 kg N/ha) would be sufficient to sustain the productivity of aromatic rice under North Indian conditions.

REFERENCES

Bharde, N.M., Shivay, Y.S. and Singh, S. 2003. Effect of biogas slurry and neem oil treated urea sources on rice (*Oryza sativa*) - wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **48**(2): 73–77.

Bharde, N.M., Shivay, Y.S., Prasad, R., Kumar, D. and Singh, S. 2006. Effect of blending urea with neem-oil with and without biogas slurry on rice-wheat cropping system. *Indian Journal of Fertilizers* **2**(7): 37–42.

FAI. 2007. *Fertilizer Statistics* (2006-2007). The Fertilizer Association of India, New Delhi.

Ladha, J.K., Pathak, H., Krupnik, T.J., Six, J. and Kessel, C.V. 2005. Efficiency of fertilizer nitrogen in cereal production: Retrospect and Prospects. *Advances in Agronomy* **87**: 87–155.

Oo, N.M.L., Shivay, Y.S. and Kumar, D. 2007. Effect of nitrogen and sulphur fertilization on yield attributes productivity and nutrient uptake of aromatic rice (*Oryza sativa*). *Indian Journal of Agricultural Sciences* **77**(11): 772–775.

Sato, S. and Morgan, K.T. 2008. Nitrogen recovery and transformation from a surface or sub-surface application of controlled-release fertilizer on a sandy soil. *Journal of Plant Nutrition* **31**: 2214–2231.

Shivay, Y.S. 2007. Effect of levels and neem (*Azadirachta indica* A. Juss.) coated urea sources of nitrogen on productivity and nitrogen recovery of rice under Indo-Gangetic plains. *International Journal of Tropical Agriculture* **25**(4): 1111–1123.

Shivay, Y.S., Prasad, R., Singh, S. and Sharma, S.N. 2001. Coating of prilled urea with neem (*Azadirachta indica* A. Juss.) for efficient nitrogen use in lowland transplanted rice. *Indian Journal of Agronomy* **46**(3): 453–457.

Singh, S. and Shivay, Y.S. 2003. Coating of prilled urea with ecofriendly neem (*Azadirachta indica* A. Juss.) formulations for efficient nitrogen use in hybrid rice. *Acta Agronomica Hungarica* **51**(1): 53–59.