



Dual purpose summer legumes and zinc fertilization for improving productivity and zinc utilization in aromatic hybrid rice (*Oryza sativa*)

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ABSTRACT

Field experiments were conducted during 2007-08 at New Delhi, to study the effect of dual purpose summer legumes and zinc (Zn) fertilization on productivity and Zn-use efficiency of aromatic hybrid rice cv 'Pusa Rice Hybrid 10' ('PRH 10'). The experiment was carried out in split plot design with 3 treatments of legume residue in main plots and seven treatments of Zn fertilization in sub-plots. The tallest plant height, number of tillers/m², dry matter accumulation/hill, leaf area index (LAI), yield attributes and grain yield of aromatic hybrid rice was recorded with incorporation of cowpea residue followed by mungbean residue. Zinc fertilization in aromatic hybrid rice increased growth parameters, yield attributes, grain and straw yields. Application of 2% ZEU (ZnSO₄·7H₂O) was found to be the best in terms of all the yield attributes, grain yield of aromatic hybrid rice, 2% ZEU (ZnO) was found very close to it. In respect to Zn concentrations in grain and straw of aromatic hybrid rice, 2% ZEU (ZnSO₄·7H₂O) recorded higher Zn concentrations in grain as well as in straw of aromatic hybrid rice. The highest agronomic efficiency (AE) was obtained with the application of 2% ZEU (ZnSO₄·7H₂O). Physiological efficiency (PE) and Zn harvest index (ZnHI) of applied Zn were also significantly influenced due to dual purpose summer legumes and various Zn fertilization treatments applied in aromatic hybrid rice. Cooking quality parameters were significantly improved by legume residue incorporation and with the application of ZEU. The highest net returns and B:C ratios of the legume-rice sequence were recorded with the legume residue incorporation and with the application of ZEU in the aromatic hybrid rice. Thus, growing of cowpea or mungbean as dual purpose summer legumes along with Zn fertilization as 2% ZEU either with ZnSO₄·7H₂O or ZnO to aromatic hybrid rice led to higher productivity, cooking quality and Zn-use efficiency in aromatic hybrid rice and higher net returns of this sequence.

Key words: Cooking quality, Cowpea, Economics, Growth parameters, Mungbean, Zinc-enriched urea, Zinc-uptake, Zinc-use efficiency

Zinc (Zn) deficiency in soil is well known problem that causes reduced agricultural productivity all over the world. In addition, it causes Zn deficiency in humans, especially in developing countries where diets are cereals based and poor in animals and fish products. The deficiency of Zn is especially widespread in high pH calcareous soils. An analysis of 233 lakh soil samples taken from different states showed that 47% of Indian soils are deficient in Zn. In India, Zn deficiency is widespread in the rice-wheat cropping system belt of North India, which has high pH calcareous soils (Prasad, 2005). Increase in soil pH is associated with increased sorption of Zn on soil hydroxide, carbonates and organic matter and increased absorption by plant roots. Zinc deficiency in rice creates brown spots or burning appearance of leaves, which appears first in the younger leaves and under severe deficiency appears on

lower leaves also. In severe deficiency burnt dark brown patches of plants appear in rice fields. Response of rice to Zn has been reported by several workers in India (Shivay *et al.*, 2008), China and USA (Slaton *et al.*, 2005). Zinc is now recognized as the fifth leading risk factor in developing Asian countries and efforts are underway for encouraging Zn fertilization not only from the view point of getting higher yields but also for increasing Zn concentrations in grain and straw to improve human and animal Zn nutrition. Soil application of 5 kg Zn/ha (25 kg ZnSO₄·7H₂O/ha) is recommended for rice in India. However, the product is quite costly and generally not available to farmers' resulting reduced rice yield. An attempt was therefore being made to develop Zn-enriched urea (2%) that would permit an easy access to Zn to the rice grower in Asia. This practice has advantage that much smaller quantities of Zn are needed. Paddy soils are usually deficient in organic matter because of high temperature and moisture, which

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causes rapid decomposition of organic matter. The positive effect of green manures on paddy yield has been reported by many workers in India. Incorporation of *Sesbania* or other green manuring crops i.e. cowpea and mungbean before transplanting of rice can ameliorate the Fe and Mn deficiency by promoting reduced condition besides improving other physico-chemical properties of soil. Hemalatha *et al.* (1999) observed that *in-situ* incorporation of *Sesbania* before transplanting of rice increased the grain yield by 18% and straw yield by 16% as well as quality of rice. Therefore considering the importance of summer green manuring and Zn fertilization for increasing the productivity and improving the Zn-use efficiency a field experiment was undertaken to study the effect of dual purpose summer legumes cowpea and mungbean and Zn fertilization on productivity and Zn use-efficiency in aromatic hybrid rice.

MATERIALS AND METHODS

Field experiments were conducted during rainy seasons of 2007 and 2008 at the research farm of Indian Agricultural Research Institute, New Delhi, situated at latitude of 28°40' N and longitude of 77°12' E, altitude of 228.6 meters above the mean sea level (Arabian Sea). The mean annual rainfall of Delhi is 650 mm and more than 80% generally occurs during the south-west monsoon season (July-September). The soils of experimental field had 135.5 kg/ha alkaline permanganate oxidizable N, 16.2 kg/ha available P, 276.5 kg 1 N ammonium acetate exchangeable K and 0.53% organic carbon. The pH of soil was 7.5 (1: 2.5 soil and water ratio) and DTPA-extractable Zn in soil was 0.67 mg/kg of soil. The critical level of DTPA-extractable Zn for rice grown in alluvial soils in rice-wheat belt in north India varies from 0.38-0.90 mg/kg. The experiment was laid out in split-plot design with 3 treatments comprising dual purpose summer legumes cowpea, mungbean residue incorporation and summer fallow were taken in main plots and 7 treatments of Zn fertilization i.e. absolute control (no N and no Zn), control (only N), 2% Zn-enriched urea (ZEU) as $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, 2% ZEU as ZnO, 5 kg Zn/ha through $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ as soil application, 5 kg Zn/ha through ZnO as soil application, coating material coated urea (CMCU), respectively were allocated in sub-plots and replicated thrice. Nitrogen at the rate of 150 kg/ha was applied in all the treatments except absolute control. The experimental field was disc-ploughed twice, puddled thrice with heavy puddler in standing water and leveled. At final puddling 26 kg P/ha as SSP and 33 kg K/ha as MOP were broadcast, N as prilled urea or ZEU was applied into two equal splits; half at the time of transplanting and remaining half at panicle initiation stage (40 days after transplanting). All Zn fertilization treatments either

by ZEU as 2% through $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ or ZnO or direct soil application through $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ or ZnO supplied 5 kg Zn/ha. One additional treatment of coating material coated urea (CMCU) was also applied. One 25-days-old seedling of aromatic hybrid rice 'PRH 10' was transplanted on hills at 20 cm x 15 cm in the first fortnight of July in both the year of field study. The plot size was 5.0 m x 1.5 m for each treatment. Rice was grown as per recommended practices and was harvested in the second fortnight of October in both the year of experimentation.

Plant samples collected at harvest were dried in hot air oven at $60 \pm 2^\circ\text{C}$ for 6 hours. The oven-dried samples of plants and air-dried sample of grain were ground to pass through 40 mesh sieve in a Macro-Wiley Mill. From each replication 0.5 g grain and straw samples were taken for chemical analysis to determine the Zn concentrations as per the procedure described by Prasad *et al.* (2006). The estimated values of partial factor productivity (PFP), agronomic efficiency (AE), crop recovery efficiency (CRE), physiological efficiency (PE) and Zn harvest index (ZnHI) of applied Zn were computed using the expressions suggested by Dobermann (2005).

Ten grains with husks from each replication were selected and were used for measuring their length/breadth after cooking on a graph paper using a 'Photo Enlarger' with a magnification of 3X. The actual mean of grain length/breadth was expressed in mm. Economics of dual-purpose summer legumes-aromatic hybrid rice cropping sequence was calculated based on the prevailing prices of inputs and outputs during respective crop seasons.

The data relating to each character were analyzed as per the procedure of analysis of variance and significance was tested by "F" test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Performance of dual purpose summer legumes

Between two dual purpose summer legumes, cowpea recorded significantly higher total dry matter accumulation (Table 1). Significantly higher total N and Zn accumulation (root + shoot) was recorded in cowpea residue compared to mungbean residue. This was due to higher dry matter accumulation in cowpea which accumulated more N and Zn than the mungbean. Cowpea also recorded significantly higher available N in soil after harvest compared to mungbean and summer fallow while available Zn was higher with both legumes over the summer fallow. Incorporation of legume residue over the years increased organic carbon content of soil which may also be responsible for higher nitrogen and zinc availability in soil.

Growth parameters

All the growth parameters of aromatic hybrid rice were

significantly influenced due to preceding dual purpose summer legumes residue incorporation. The plant height, tillers/m² and dry matter accumulation at harvest and leaf area index (LAI) at 60 days after transplanting (DAT) after incorporation of cowpea residue were significantly higher over mungbean and summer fallow (Table 2). This was due to residual effect of biological N fixed in the root nodules of previous dual purpose summer grain legume cowpea and to a lesser degree by the mungbean. Supply of nitrogen and numbers of tillers have positive correlation. The higher availability of N in balanced form with other nutrients after incorporation of legume residue led to significant improvement in plant growth and finally increased dry matter accumulation. Adequate and continuous availability of nutrients with adequate level of fertilizer N also improved the LAI of aromatic hybrid rice. Meena and Shivay (2010) also reported the similar findings.

A significant increase in growth attributes of aromatic hybrid rice was recorded due to Zn fertilization. The plant

height, tillers/m² and dry matter accumulation at harvest and LAI at 60 DAT was observed higher with 2% ZEU (ZnSO₄.7H₂O) at all growth stages in both the years. The increase in plant height and tillers/m² due to proper supply of N and Zn from ZEU was recorded. Zinc nutrition is known to increase tillering in rice, which might have caused a significant increase in dry matter production (Ghatak *et al.*, 2005). Slaton *et al.* (2005) have also observed an increase in dry matter accumulation of rice by application of Zn. Application of Zn, from Zn-coated urea and other sources is reported to have beneficial effect on LAI (Grewal *et al.*, 1997).

Yield attributes

Numbers of effective tillers/m² and grains/panicle and 1,000-grains weight were positively influenced due to preceding dual purpose summer legumes (Table 3). Accumulation of more N and other nutrients in cowpea residue and further its supply to succeeding rice led to better source-

Table 1. Dry matter, N and Zn accumulation and residual fertility effects of dual purpose summer legumes

Treatment	Total dry matter accumulation (t/ha)		Total N accumulation in residue (kg/ha)		Total Zn accumulation in residue (g/ha)		Organic carbon (%)		Available N (kg/ha)		Available Zn (mg/kg of soil)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
	Mungbean	2.86	3.00	72.46	79.89	198.8	221.0	0.55	0.56	163.6	158.4	0.76
Cowpea	4.17	4.32	97.92	106.53	301.6	328.1	0.56	0.56	175.6	171.8	0.77	0.76
Summer fallow	-	-	-	-	-	-	0.52	0.52	132.6	128.3	0.67	0.67
SEm ±	0.06	0.06	2.22	2.45	3.09	3.02	0.01	0.01	2.09	2.38	0.020	0.015
CD (P=0.05)	0.36	0.37	13.49	14.93	18.81	18.39	0.03	0.03	7.24	9.33	0.079	0.059

Table 2. Effect of dual purpose summer legumes and Zn fertilization on growth parameters of aromatic hybrid rice

Treatment	Plant height at harvest (cm)		Tillers/m ² at harvest		Dry matter accumulation at harvest (g/hill)		LAI [#] at 60 days after transplanting (DAT)	
	2007	2008	2007	2008	2007	2008	2007	2008
	<i>Dual purpose summer legumes</i>							
Summer fallow	101.9	99.4	435	424	45.8	44.8	3.94	3.86
Mungbean	103.5	105.3	453	459	49.9	50.8	4.54	4.50
Cowpea	105.0	107.6	467	479	52.5	53.7	4.86	4.94
SEm ±	0.32	0.32	4.0	4.4	0.46	0.43	0.027	0.026
CD (P=0.05)	1.24	1.26	15.5	17.4	1.80	1.70	0.104	0.104
<i>Zn fertilization</i>								
Absolute control (no N and no Zn)	93.0	93.8	333	331	32.9	33.3	3.41	3.43
Control (only N)	102.4	103.3	420	424	49.5	49.9	4.60	4.62
2% ZEU* (ZnSO ₄ .7H ₂ O)	114.4	115.4	582	587	62.1	62.7	6.17	6.23
2% ZEU (ZnO)	107.3	108.2	511	516	55.5	56.0	5.90	5.94
5 kg Zn/ha (ZnSO ₄ .7H ₂ O)	105.4	106.3	478	482	49.7	50.2	5.37	5.41
5 kg Zn/ha (ZnO)	103.7	104.5	446	450	48.1	48.5	4.82	4.67
CMCU**	101.6	100.7	430	437	49.5	49.1	4.82	4.71
SEm ±	0.68	0.69	9.9	9.9	0.77	0.75	0.032	0.039
CD (P=0.05)	1.95	1.97	28.5	28.5	2.22	2.16	0.091	0.113

ZEU*= Zn-enriched urea; CMCU**= Coating material coated urea; LAI[#]= Leaf area index

sink relationship and it resulted into bolder seeds as compared to summer fallow and mungbean and thus gave the highest 1,000-grains weight. These results are in accordance with the findings of Meena and Shivay (2010).

Number of effective tillers/m² and grains/panicle and 1,000-grains weight were higher with 2% ZEU (ZnSO₄·7H₂O) and significantly superior to other Zn fertilization treatments and control. Adequate Zn levels in soil increased tillering and consequently the number of panicles per unit area of lowland rice. The increase in N availability through synchronized release from ZEU might be responsible for increased number of leaves, resulting in higher photosynthesis, metabolic activity and cell division, which consequently increased growth and hence yield attributes. Ghatak *et al.* (2005) also reported similar results. The N and Zn fertilization is directly responsible for higher 1,000-grains weight because N increased the crude protein content in grains (Naik and Das, 2008).

Yield

A significantly higher grain and biological yield of aromatic hybrid rice was recorded when aromatic hybrid rice was grown after incorporation of cowpea residue or mungbean as dual purpose summer legumes and it was more in 2008. Incorporation of legume crop residue before transplanting of rice may also improve rice grain yield by enhancing the availability of micronutrients by recycling them from subsurface layer to surface layer and by increasing organic carbon content of soil. Porpavai (2009) also reported similar results.

Zn fertilization had significant effect on grain and biological yield of aromatic hybrid rice and 2% ZEU

(ZnSO₄·7H₂O) recorded significantly higher yields over rest of the Zn treatments. The maximum grain yield of aromatic hybrid rice was recorded with 2% ZEU (ZnSO₄·7H₂O) which was on par to 2% ZEU (ZnO). However, in general Zn sulphate-enriched urea was a better source of Zn than Zn oxide-enriched urea. A number of studies have been made to compare the relative efficiency of different sources of Zn and some have indicated that water soluble Zn sulphate was a superior source for rice (Slaton *et al.*, 2005). Hence, due to better solubility of Zn and supply of sulphur, Zn sulphate-enriched urea produced more grain yield than ZnO-enriched urea at the same level of Zn enrichment. Increase in crop yield could be attributed to the controlled release of N and also Zn from ZEU and supply of mineralized N to the plants for longer period.

Zn concentration and uptake in aromatic hybrid rice

Significantly higher Zn concentration in grain and Zn uptake was recorded when aromatic hybrid rice was grown after incorporation of cowpea residue; it was significantly more than summer fallow but was statistically on par with mungbean incorporation during both the year of experimentation (Table 4). The percentage increases in total Zn uptake (grain + straw) of aromatic hybrid rice with preceding cowpea residue incorporation was 20.5 and 36.4 over summer fallow during 2007 and 2008, respectively. The recycling of 301.6 and 328.1 g Zn /ha by residue of cowpea during 2007 and 2008 respectively resulted in more Zn availability in aromatic hybrid rice soil and ultimately led to higher Zn uptake.

Zn fertilization had significant effect on Zn concentra-

Table 3. Effect of dual purpose summer legumes and Zn fertilization on yield attributes and yields of aromatic hybrid rice

Treatment	Effective tillers/m ²		Grains/panicle		1,000-grains weight (g)		Grain yield (t/ha)		Biological yield (t/ha)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Dual purpose summer legumes										
Summer fallow	408	398	117	114	25.50	24.71	6.11	5.80	15.75	14.95
Mungbean	434	442	120	122	26.29	26.88	7.06	7.33	18.20	18.90
Cowpea	448	460	121	124	26.90	27.72	7.10	7.41	18.38	19.12
SEm ±	4.1	4.4	0.8	0.6	0.13	0.11	0.02	0.03	0.12	0.11
CD (P=0.05)	16.0	17.3	3.2	2.2	0.51	0.44	0.07	0.10	0.48	0.43
Zn fertilization										
Absolute control (no N and no Zn)	281	284	103	104	21.31	21.56	5.15	4.90	13.67	12.99
Control (only N)	333	336	110	111	23.21	23.46	6.67	6.81	17.45	17.80
2% ZEU* (ZnSO ₄ ·7H ₂ O)	581	587	135	136	31.30	31.62	7.44	7.62	19.02	19.42
2% ZEU (ZnO)	511	516	128	129	29.31	29.61	7.22	7.37	18.48	18.85
5 kg Zn/ha (ZnSO ₄ ·7H ₂ O)	474	478	125	126	27.60	27.88	7.10	7.24	18.13	18.49
5 kg Zn/ha (ZnO)	431	435	121	122	26.49	26.77	6.97	7.11	17.78	18.13
CMCU**	398	395	115	114	24.41	24.17	6.73	6.87	17.58	17.93
SEm±	8.3	8.3	1.5	1.2	0.31	0.31	0.11	0.12	0.19	0.19
CD (P=0.05)	23.8	23.9	4.4	3.4	0.88	0.88	0.31	0.34	0.56	0.53

ZEU*= Zn-enriched urea; CMCU**= Coating material coated urea

tions in grain and straw of aromatic hybrid rice. The maximum Zn concentrations in grain and straw of aromatic hybrid rice was recorded with 2% ZEU ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$) (Table 4). Shivay *et al.* (2008) also reported that Zn concentration was the highest with higher level of Zn enrichment. Zn uptake in aromatic hybrid rice increased significantly with 2% ZEU ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$) as compared to rest of the Zn treatments during both the years. Shivay *et al.* (2008) recorded the highest total Zn uptake with 3.5% ZEU ($\text{ZnSO}_4 \cdot \text{H}_2\text{O}$). Zinc interacts positively with N, which is mainly attributed to the increased availability of Zn in soil due to acid forming effect of N (Prasad, 2005). Therefore, application of N either through ZEU or through prilled urea increased Zn uptake significantly over absolute control. The mobility of Zn in soil following fertilization differs among Zn sources and influences Zn uptake. When Zn is applied to soil surface, water soluble Zn sulphate showed much greater vertical downward movement than the relatively water insoluble Zn oxide and finally the mobility of Zn in soil directly influences the Zn uptake in rice grain, straw as well as total.

Zn-use efficiency

Preceding dual purpose summer legumes had significant effect on agronomic efficiency (AE) of aromatic hybrid rice during both the years of field study. The highest AE (kg grain increase/kg Zn applied) was recorded with mungbean residue incorporation during both the years (Table 4). Zinc fertilization had a significant effect on AE of applied Zn for aromatic hybrid rice and 2% ZEU

($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$) recorded significantly higher AE over all the other Zn fertilization treatments in both the years of experimentation. The percentage increases in AE of aromatic hybrid rice with 2% ZEU ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$) was 41.2, 80.1 and 161.5 over 2% ZEU (ZnO), 5 kg Zn/ha through $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ as soil application and 5 kg Zn/ha through ZnO as soil application during 2007, respectively. Almost similar trend was followed in 2008.

Cooking quality parameters

A significantly higher rice grain length after cooking of aromatic hybrid rice was recorded when aromatic hybrid rice was grown after incorporation of cowpea or mungbean residue. The longest rice grain length after cooking 12.8 to 13.0 mm was recorded with 5.0 kg Zn/ha (ZnO) (Table 5). Shivay (2007) also reported that modified urea fertilizers affected the aromatic hybrid rice cooking quality parameters.

Application of 2.0% ZEU ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$) recorded higher rice grain breadth after cooking during both the years of study. Significantly highest grain length breadth ratio of aromatic hybrid rice after cooking was recorded when it was grown after the incorporation of cowpea residue. Rice grain length breadth ratio after cooking was the highest in control (only N) which was on par with 5.0 kg Zn/ha (ZnO). Shivay *et al.* (2010) also reported the similar findings.

Economics

The highest gross and net returns and B:C ratio were recorded when rice was grown after the incorporation of

Table 4. Effect of dual purpose summer legumes and Zn fertilization on Zn concentrations in rice grain and straw and their uptake and Zn-use efficiency by aromatic hybrid rice

Treatment	Zn concentration (mg/kg DM) in straw		Zn concentration (mg/kg DM) in grain		Total Zn uptake in rice grain + straw (g/ha)		AE (kg grain increase/kg Zn applied)	
	2007	2008	2007	2008	2007	2008	2007	2008
<i>Dual purpose summer legumes</i>								
Summer fallow	149.7	145.9	18.1	17.6	1,554.6	1,457.8	96.7	91.5
Mungbean	153.3	156.1	19.1	19.6	1,859.8	1,946.2	109.5	114.6
Cowpea	153.1	156.9	19.1	19.6	1,873.2	1,988.7	99.5	107.7
SEm±	0.28	0.27	0.05	0.04	8.6	16.8	2.4	3.7
CD (P=0.05)	1.09	1.07	0.18	0.17	33.8	66.0	9.4	14.7
<i>Zn fertilization</i>								
Absolute control (no N and no Zn)	124.6	125.7	14.9	15.0	1,124.0	1,093.5	-	-
Control (only N)	143.3	144.6	16.9	17.1	1,653.1	1,662.3	-	-
2% ZEU* ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$)	176.9	178.4	22.9	23.1	2,219.3	2,290.3	154.0	161.2
2% ZEU (ZnO)	163.9	165.3	19.9	20.1	1,977.7	2,061.7	109.1	111.2
5 kg Zn/ha ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$)	160.6	162.0	21.0	21.2	1,934.2	1,980.4	85.5	86.1
5 kg Zn/ha (ZnO)	151.1	152.4	19.1	19.2	1,754.6	1,824.8	58.9	59.9
CMCU**	143.7	142.5	17.0	16.9	1,675.1	1,669.7	-	-
SEm±	0.56	0.56	0.08	0.08	22.1	37.6	0.9	2.6
CD (P=0.05)	1.60	1.60	0.24	0.24	63.4	107.8	2.8	7.6

ZEU* = Zn-enriched urea; CMCV** = Coating material coated urea; DM = Dry matter; AE = Agronomic efficiency

Table 5. Effect of dual purpose summer legumes and Zn fertilization on cooking quality of aromatic hybrid rice and economics of legume-aromatic hybrid rice cropping sequence

Treatments	Rice grain length after cooking (mm)		Rice grain breadth after cooking (mm)		Rice grain length breadth ratio after cooking		Gross return ($\times 10^3$ ₹/ha)		Net return ($\times 10^3$ ₹/ha)		Benefit: cost ratio	
	2007	2008	2007	2007	2007	2008	2007	2008	2007	2008	2007	2008
	<i>Dual-purpose summer legumes</i>											
Summer fallow	11.9	11.5	2.61	2.55	4.57	4.50	69.05	74.50	43.17	48.29	1.66	1.83
Mungbean	12.7	13.1	2.63	2.68	4.82	4.88	98.87	123.27	67.56	91.56	2.15	2.88
Cowpea	12.8	13.2	2.64	2.69	4.84	4.91	105.49	126.85	73.23	94.18	2.27	2.87
SEm \pm	0.05	0.03	0.01	0.01	0.02	0.03	0.71	0.64	0.71	0.64	0.02	0.02
LSD (P=0.05)	0.18	0.13	NS	0.04	0.09	0.10	2.77	2.53	2.77	2.53	0.09	0.08
<i>Zinc fertilization</i>												
Absolute control (no N & no Zn)	12.0	12.2	2.53	2.55	4.76	4.78	73.84	83.99	47.30	57.08	1.75	2.07
Control (only N)	12.7	12.8	2.57	2.59	4.94	4.96	90.71	108.29	60.68	77.88	2.00	2.51
2.0% ZEU* (ZnSO ₄ .7H ₂ O)	12.7	12.9	2.70	2.72	4.71	4.72	98.46	117.61	67.92	86.69	2.20	2.76
2.0% ZEU (ZnO)	12.6	12.8	2.69	2.71	4.70	4.74	96.01	114.56	65.47	83.64	2.12	2.66
5.0 kg Zn/ha (ZnSO ₄ .7H ₂ O)	12.2	12.4	2.66	2.68	4.59	4.61	94.58	112.88	64.06	81.98	2.08	2.61
5.0 kg Zn/ha (ZnO)	12.8	13.0	2.63	2.65	4.87	4.89	93.05	111.13	62.54	80.23	2.03	2.55
CMCU**	12.1	12.0	2.60	2.58	4.66	4.66	91.32	108.99	61.27	78.56	2.01	2.54
SEm \pm	0.07	0.06	0.01	0.01	0.04	0.04	0.44	0.69	0.49	0.69	0.02	0.02
LSD (P=0.05)	0.19	0.18	0.04	0.04	0.10	0.11	1.41	1.97	1.49	1.97	0.05	0.07

ZEU*= Zn-enriched urea; CMCU**= Coating material coated urea

cowpea residue and these were lowest when rice was grown after summer fallow. Application of 2.0% ZEU (ZnSO₄.7H₂O) recorded significantly higher gross and net returns and B:C ratio during both the years of study. Significant effect of Zn-enriched urea on higher returns and B:C ratio in rice-wheat cropping system have been reported by Shivay *et al.* (2008).

Based on two years of field study it can be concluded that growing of aromatic hybrid rice after the incorporation of summer cowpea or mungbean residue along with application of 2% ZEU results in higher productivity, Zn-enrichment in grain and straw, enhanced cooking quality and higher economic returns.

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