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Original Research Article

Yield and Quality of Rice-Greengram System as Influenced by Zinc Fortification

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Keywords

Cropping system, Fortification, Rice, Rice-fallow greengram, Quality, Yield, Zinc content, $ZnSO_4$

A B S T R A C T

A field experiment was conducted during *kharif* and *rabi*, 2015-16 on clay loam soils of Regional Agricultural Research Station, Anakapalle to study the yield and quality of rice-greengram system as influenced by zinc fortification. The experiment was laid out in a randomized block design with six treatments in four replications for rice crop during *kharif* and in *rabi* each of these six treatments were further subdivided into three subplots each in split plot design and replicated four times for the rice fallow greengram. The results revealed soil application of 50 kg $ZnSO_4$ ha^{-1} along with foliar application of 0.2% $ZnSO_4$ at panicle emergence to *kharif* rice significantly enhanced the yield attributes and yield by 11.6 to 15.9 per cent as compared to no application of zinc. Similarly, foliar application of 0.2% $ZnSO_4$ to rice fallow greengram at flowering significantly improved the yield and quality of rice fallow greengram and hence application of Zinc to rice-greengram system has improved the productivity and quality of this cropping system.

Introduction

Cropping system has attained great significance in intensified agriculture in India, to overcome the drawbacks of mono cropping system to exploit the soil intensively for enhanced food production. Rice-rice fallow green gram is the major cropping system in North Coastal Zone of Andhra Pradesh. The area under the rice and greengram in Andhra Pradesh is 1.484 million hectares and 0.123 million hectares respectively. Of these 31,007 hectares is under the rice-greengram system in the north coastal zone of A.P. Rice (*Oryza sativa L.*) is the most important cereal crop in the developing world and is the staple food of over half the world's population. It is cultivated in an area of 38.35 million hectares with a productivity of 2375 kg ha^{-1} (Ministry of Agriculture, Govt. of India, 2015). Pulses also play an important role in human diet consisting of rich source of proteins, vitamins and important amino acids. The productivity of pulse crops in the north coastal zone of Andhra Pradesh is (5-7q/ha).

Rice is a poor source of many essential mineral nutrients, especially Zn and Fe, which are required for human nutrition. Cereal crops play an important role in satisfying daily calorie intake in developing world, but they are inherently very low in Zinc concentrations in grain, particularly when grown on Zinc deficient soils. Zinc deficiency is a serious nutritional problem, affecting an estimated one third population in the developing countries of the world (Dhaliwal *et al*. 2010). Zinc is now recognized as the fourth major micronutrient deficiency in humans and ranked after vitamin A, iron and iodine deficiencies. Zn plays an important role in production of protein and thus helps in wound healing, blood formation and growth and maintenance of tissue (Bell and Dell, 2008). Improving the nutritive value of rice by increasing zinc levels in grain in addition to rice productivity not only leads to food security but also nutritional security of people.

In case of greater bioavailability of the grain Zn derived from foliar application and from soil, agronomic biofortification would be a very attractive and useful strategy in solving Zn deficiency-related health problems globally (Cakmak, 2008). Hence, a trial was undertaken to study the effect of zinc on yield and the content of Zn in grains of rice in rice-greengram system.

Materials and Methods

A field experiment was conducted during *kharif* and *rabi*, 2015-16 at Regional Agricultural Research Station, Anakapalli. The soil was clay loam in texture with a neutral pH of 7.42 and EC of 0.22 dSm^{-1}, medium in organic carbon (0.64%), low in available nitrogen (200.7 kg ha^{-1}), medium in available phosphorus (22.1 kg ha^{-1}), high in available potassium (358.4 kg ha^{-1}) and low in available zinc (0.37 ppm). The experiment was laid out in a randomized block design with six treatments in four replications for rice crop during *kharif* and in *rabi* each of these six treatments were further subdivided into three subplots each in split plot design and replicated four times for the rice fallow greengram. During *kharif*, rice variety MTU-1001 was transplanted by adopting a spacing of 20 x 10 cm. A recommended dose of 120 kg N, 60 kg P_2O_5 and 50 kg K_2O ha^{-1} was applied through urea, single superphosphate and muriate of potash respectively. During *rabi*, greengram was sown immediately after harvesting the rice crop. Data on growth and yield parameters were recorded from five randomly selected plants in each treatment; grain yield (kg plot-1) was calculated from whole plot and converted into kg ha-1 along with grain/seed content of Zinc was recorded. Statistical analysis of all the data collected are carried out following the analysis of variance technique for randomized block design (RBD) and split plot design as outlined by Gomez and Gomez, 1984. Zinc content in the plants was estimated by using Atomic Absorption Spectrophotometer method, Lindsay and Norvell, 1978.

Results and Discussion

Yield attributes of rice

Productive tillers m^{-2}

Productive tillers m^{-2} (Table 1) was significantly influenced by the various treatments tested for this study. Among the different treatments soil application of 50 kg $ZnSO_4$ ha^{-1} + 0.2% spray of $ZnSO_4$ at panicle emergence (M_5) resulted in the highest number of productive tillers m^{-2} which was on a par with soil application of 62.5 kg $ZnSO_4$ ha^{-1} (M_4) Productive tillers with M_6 was on a par with M_5, M_4 and M_3 and was in disparity with M_2 and M_1. M_3 was superior to M_1 and in parity with rest of the treatments. This increase in productive tillers due to soil and foliar application of zinc might be due to increased photosynthetic rate, excessive accumulation of sucrose, glucose and fructose in leaves, which might have increased the physiological parameters of the plant.

Similar findings were also reported by Sharma *et al*. (1999), Reddy *et al*. (1984) and Ravikiran and Reddy (2004b). Number of productive tillers observed least in M_1 was on a par only with M_2 and found significantly inferior to all the remaining treatments. The lower number of productive tillers can be attributed to lower uptake of zinc in M_1 treatment, which became a limiting nutrient.

Number of filled grains panicle^{-1}

The maximum number of filled grains panicle^{-1} (Table 1) was with application of 50 kg $ZnSO_4$ ha^{-1} + 0.2% spray of $ZnSO_4$ at panicle emergence (M_5) which was on a par with soil application of 62.5 kg $ZnSO_4$ ha^{-1} (M_4) and application of 50 kg $ZnSO_4$ ha^{-1} + 0.2% spray of $ZnSO_4$ at flowering (M_6) but significantly differed with M_3 (soil application of 50 Kg $ZnSO_4$ ha^{-1}), M_2 (soil application of 37.5 Kg $ZnSO_4$ ha^{-1}) and M_1 (Control-No zinc) where as M_4 and M_6 were statistically similar to M_5 and M_3 and was found to be significantly superior over M_2 and M_1 which were on par with each other. Number of filled grains panicle^{-1} registered with M_2 was on a par with M_3 and M_1, where as M_1 has registered the least filled grains panicle^{-1} which was comparable only to M_2 and found significantly inferior to rest of the treatments. As zinc plays a key role in chlorophyll synthesis, the higher chlorophyll content due to soil and foliar application of zinc might have lead to faster grain filling through increased photosynthetic rate. The contribution of carbohydrates from photosynthetic activity for longer period might have resulted in efficient translocation of food material into the sink (grain) and thereby increased the number of filled grains panicle^{-1}. These results are in conformity with the findings of Ravikiran and Reddy, (2004a); Rathore *et al*. (2004); Khan *et al.* (2003); Ram *et al*. (1995).

Test Weight (1000- grain weight)

The data (Table 1) pertaining to the thousand grain weight revealed that there was no significant difference in thousand grain weight due to zinc application clearly indicating that it is a character mostly governed by genetic influence of the crop where environmental and managerial factors usually have less influence on it.

Grain and Straw yield

Significant increase in grain and straw yields by rice plant was observed with the zinc treatments (Table 1 and Figure 1). The highest grain yield and straw yield were recorded with soil application of 50 kg $ZnSO_4$ ha^{-1} + 0.2% spray of $ZnSO_4$ at panicle emergence (M_5) which was on a par with that of soil application of 62.5 kg $ZnSO_4$ ha^{-1} (M_4) and both of them were comparable with application of 50 kg $ZnSO_4$ ha^{-1} + 0.2% spray of $ZnSO_4$ at flowering (M_6) and soil application of 50 Kg $ZnSO_4$ ha^{-1} (M_3) while they were significantly superior to rest of the treatments i.e., M_2 (soil application of 37.5 Kg $ZnSO_4$ ha^{-1}) and M_1 (Control-No zinc).The lowest grain and straw yields were registered in M_1 was comparable only with M_2 and was found significantly inferior to the rest of the treatments.

Quality characters of rice

With respect to quality characters of rice (Table 1 and Figure 2), significant differences in zinc content in grain was noticed while hulling, milling and head rice recovery was not influenced by these treatments. Highest zinc content in rice grain was recorded with soil application of 50 kg $ZnSO_4$ ha^{-1} + 0.2% spray of $ZnSO_4$ at panicle emergence (M_5) statistically similar with application of 50 kg $ZnSO_4$ ha^{-1} + 0.2%

spray of $ZnSO_4$ at flowering (M_6) which were on a par with that of soil application of 62.5 kg $ZnSO_4$ ha^{-1} (M_4) while M_4 was on a par with M_3 (soil application of 50 Kg $ZnSO_4$ ha^{-1}). The lowest zinc content in rice grain was noticed with M_1 (Control-No zinc) remained on a par with M_2 (soil application of 37.5 Kg $ZnSO_4$ ha^{-1}) and were significantly inferior to the rest of the treatments. The increased zinc content in grain might be due to direct application of zinc at critical growth stages, which might have helped in increased absorption in the grain during ripening and also due to its direct absorption in plant tissue resulted in increased grain content of zinc. Similar findings were also reported by Khan *et al*. (2003); Stalin *et al*. (2011); Srivastava *et al*. (1992); Cakmak (2008) who reported that zinc application to zinc deficient soil increased the total biomass, grain yield**,** zinc concentration in the grain and uptake of zinc by the straw and the grain. The grain Zn was significantly increased with Zn application (soil+foliar) over no Zn application (M_1). The present results might be due to translocation of Zn from leaf to the grain and are in agreement with the results reported by Ram *et al*. (2011); Savithri *et al*. (1999); Dhaliwal *et al*. 2010.

Hence it can be concluded that soil application of 50 kg $ZnSO_4$ ha^{-1} + 0.2% spray of $ZnSO_4$ at panicle emergence to rice was found to improve the yield and zinc content in rice grain.

Yield attributes of rice fallow greengram

Number of pods plant^{-1}

Data regarding number of pods plant^{-1} was presented in Table 2. There was no significant difference observed among the treatments of main plots with respect to the number of pods plant^{-1} but with the treatments of subplots resulted in significant disparity among the treatments. The highest number of pods plant^{-1} was registered with 0.2% spray of $ZnSO_4$ at 25 DAS + 0.2% spray of $ZnSO_4$ at flowering (S_3) which was on a par with 0.2% spray of $ZnSO_4$ at flowering (S_2) and both of them were significantly superior over S_1 (0.2% spray of $ZnSO_4$ at 25 DAS). The interactions were found to be non significant between the treatments of main and sub plots.

Pod bearing branches is a phenomenon of plant growth and zinc has ability to produce plant growth regulators (Auxins, IAA). The growth and development of rice fallow greengram might be regulated by these compounds. Application of zinc sulphate helps in more pod bearing branches as it contributes to the formation of stamens as well as pollens these results are in conformity with Nadergoli *et al.,* 2011 and Taliee *et al.,* 2000.

Number of seeds pod^{-1}

Data pertaining to the influence of zinc on rice fallow greengram for number of seeds pod^{-1} are depicted in Table 2. There was no significant difference observed among the treatments of main plots, subplots and the interactions.

Test weight (100 grain weight)

The data (Table 2) pertaining to the hundred grain weight revealed that there was no significant difference in hundred grain weight due to zinc application among main plots and subplots.

Seed yield and haulm yield

The influence of zinc on seed yield of rice fallow greengram applied in rice crop was found to be non significant in the main plots, where as when zinc were sprayed to greengram at different stages of the crop in the subplots, highest seed yield was recorded with foliar application of 0.2% spray of $ZnSO_4$ at 25 DAS + 0.2% spray of $ZnSO_4$ at flowering (S_3) which was on a par with foliar application of 0.2% spray of $ZnSO_4$ at flowering (S_2) and both of them were significantly superior over S_1 (foliar application of 0.2% spray of $ZnSO_4$ at 25 DAS). There was no interaction observed between the treatments of main and sub plots.

Haulm yield was depicted in the Table 2 and Figure 3 followed exactly the similar trend as that of seed yield without any deviation. The results of this study revealed that application of zinc either alone or in combination with foliar spray to *kharif* rice did not influence the seed and haulm yield of rice fallow greengram which indicated that there is no carry over effect of zinc application to rice on rice fallow greengram. For this reason, there was response to foliar application of zinc in greengram and the highest values of seed and haulm yield were recorded with 0.2% spray of $ZnSO_4$ at 25 DAS and flowering. However, even a single spray of 0.2% $ZnSO_4$ at flowering also produced comparable yields and hence a single foliar spray at flowering will also be beneficial for greengram.

Zinc plays a vital role in plant nutrition, which is clear from its involment in process of photosynthesis and sugar translocation. The increase in seed and haulm yields due to foliar application of zinc might be due to the concomitant increase in number of pods per plant, and drymatter accumulation, these results are in conformity to those of Rizk and Abdo (2001) and Mali *et al.*(2001).

Table.1 Yield attributes, yield and Zinc content of rice in rice-greengram system as influenced by different zinc treatments

Treatment	Productive tillers m^{-2}	No.of filled grains $panicle^{-2}$	Thousand grain weight (g)	Grain yield (Kg ha^{-1})	Straw yield (Kg ha^{-1})	Grain (ppm)	Straw (ppm)
M_1 : Control	259	120	21.2	5070	6585	20.0	56.9
M_2 : 37.5 kg $ZnSO_4$ ha^{-1}	276	129	22.2	5205	6751	22.0	62.3
M_3 : 50 kg $ZnSO_4$ ha^{-1}	290	141	22.3	5614	7262	25.0	77.3
M_4 : 62.5 kg $ZnSO_4$ ha^{-1}	312	152	22.6	5709	7325	27.0	84.3
M_5 : 50 kg $ZnSO_4$ ha^{-1} + 0.2% spra y of $ZnSO_4$ at panicle emergence	318	158	23.1	5878	7481	29.5	87.0
M_6 : 50 kg $ZnSO_4$ ha^{-1}+ 0.2% spray of $ZnSO_4$ at flowering	305	150	22.7	5661	7293	29.5	90.1
SEm±	9.36	5.99	0.7	158.4	183.37	0.92	2.55
CD (P= 0.05)	28	18	NS	477	552	2.7	7.7
CV (%)	6.38	8.46	6.3	5.73	5.15	7.23	6.70

Table.2 Yield attributes, yield and zinc content of rice fallow greengram as influenced by different zinc treatments

Treatment	Number of pods per plant	Number of seeds per pod	Hundred seed weight (g)	Seed yield (Kg ha^{-1})	Haulm yield (Kg ha^{-1})	Seed (ppm)	Haulm (ppm)
Main plots : Rice **M_1** : Control	6.8	9.6	4.2	601	2118	29.6	41.9
M_2 : 37.5 kg $ZnSO_4$ ha^{-1}	6.8	10.0	4.2	609	2121	30.8	43.2
M_3 : 50 kg $ZnSO_4$ ha^{-1}	7.0	10.0	4.3	625	2128	31.2	43.5
M_4 : 62.5 kg $ZnSO_4$ ha^{-1}	7.5	9.4	4.3	669	2202	34.6	47.0
M_5 : 50 kg $ZnSO_4$ ha^{-1} + 0.2% spray of $ZnSO_4$ at panicle emergence	7.1	9.1	4.3	657	2187	32.8	45.1
M_6 : 50 kg $ZnSO_4$ ha^{-1}+ 0.2% spray of $ZnSO_4$ at flowering	7.3	9.9	4.3	674	2256	33.6	45.9
SEm±	0.29	0.36	0.05	25.41	71.38	1.44	1.44
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS
CV (%)	14.60	13.28	5.08	13.77	8.40	15.63	11.30
Sub plots : Rice fallow Green gram **S_1** : 0.2% spray of $ZnSO_4$ at 25 DAS	5.8	9.7	4.2	587	1886	27.9	38.9
S_2 : 0.2% spray of $ZnSO_4$ at flowering	7.5	9.8	4.2	647	2228	33.0	46.0
S_3 : S_1 + S_2	8.0	9.4	4.3	685	2392	35.4	48.4
SEm±	0.19	0.21	0.03	20.09	39.05	0.98	0.98
CD (P= 0.05)	0.5	NS	NS	58	116	2.8	2.8
CV (%)	13.91	11.22	4.59	15.40	9.60	15	10.84
MxS	NS	NS	NS	NS	NS	NS	NS

Fig.1 Grain yield and straw yield of rice as influenced by zinc fortification

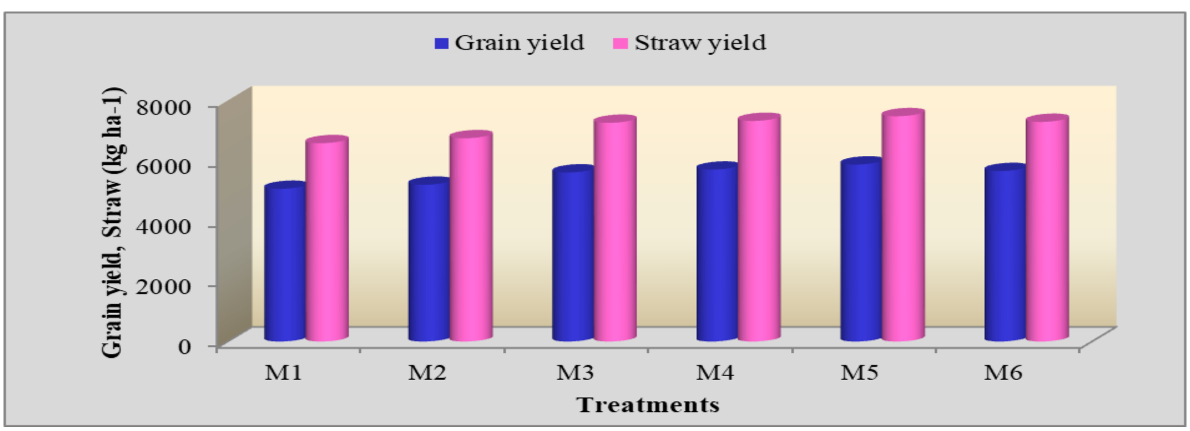


Fig.2 Zinc content in rice grain and straw as influenced by zinc fortification

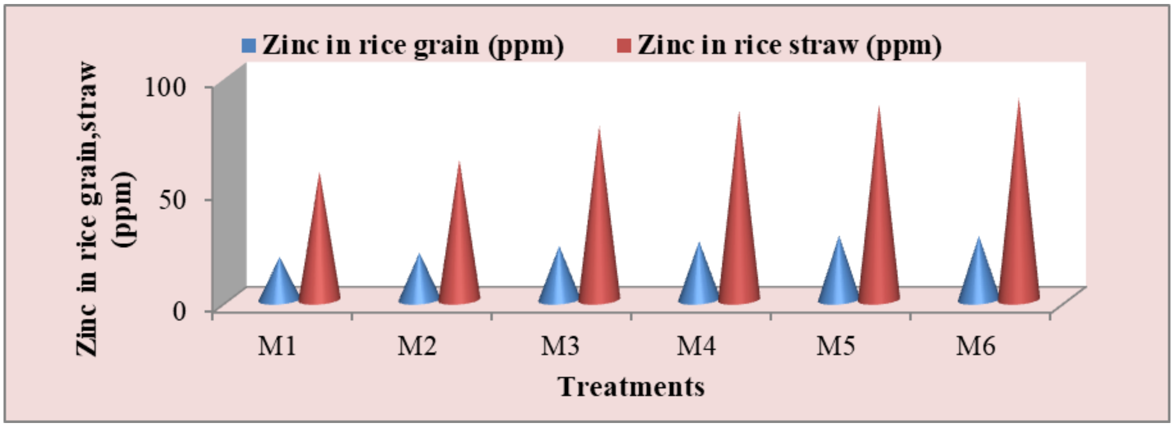


Fig.3 Seed and haulm yield of rice fallow green gram as influenced by zinc fortification

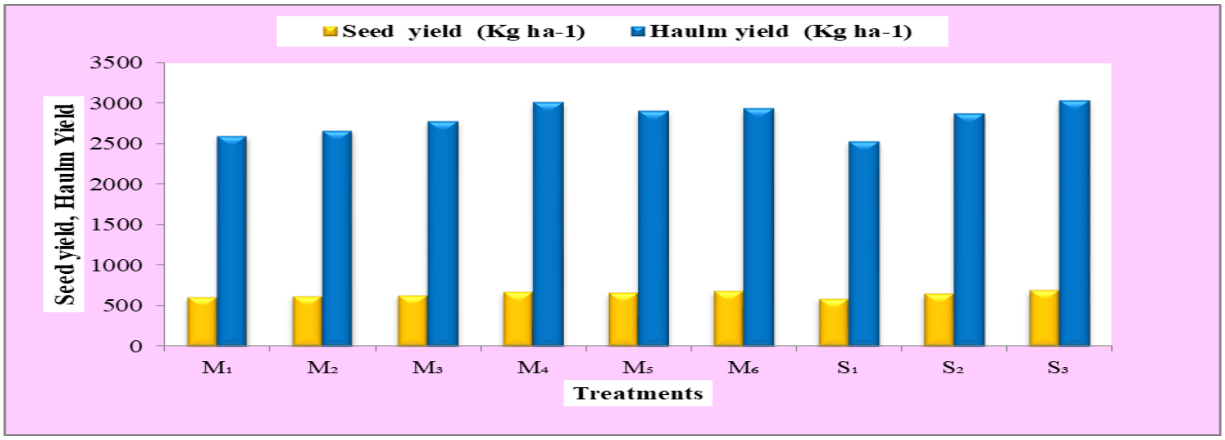
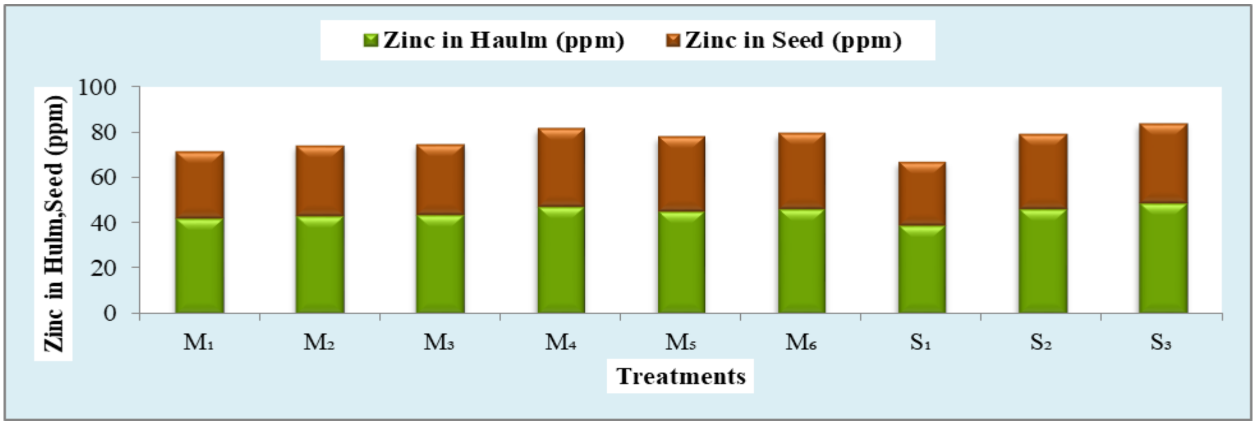


Fig.4 Zinc content in Seed and haulm of rice fallow green gram as influenced by zinc fortification



Quality parameters of rice fallow greengram

Zinc content in seed

Table 2 and Figure 4 depicted the content of zinc in seed of rice fallow greengram which showed that there were significant differences in zinc content of seed in response to zinc treatments only in the sub plots while they were non significant with main plots and for their interaction effects.

When zinc was sprayed to greengram at different stages of the crop in the subplots, highest seed yield was recorded with foliar application of 0.2% spray of $ZnSO_4$ at 25 DAS + 0.2% spray of $ZnSO_4$ at flowering (S_3) which was on a par with foliar application of 0.2% spray of $ZnSO_4$ at flowering (S_2) and both of them were significantly superior over S_1 (foliar application of 0.2% spray of $ZnSO_4$ at 25 DAS).

Zinc content in haulm

The content of zinc in haulm of rice fallow greengram showed that there was no significant difference among the treatments of main plots but showed disparity in the subplots with the trend as similar to that of zinc content in seed. The interactions between the main and subplots remained non significant.

The Zn content in haulm and seed increased with increasing level of Zn up to certain level might be due to better uptake and utilization, similar results were drawn with the application of 5 kg Zn ha^{-1} in summer green gram by Prodip Chandra Karmakar *et al*. (2015).

Based on the findings of the investigation, it can be concluded that soil application of 50 kg $ZnSO_4$ ha^{-1} along with foliar application of 0.2% $ZnSO_4$ at panicle emergence or at flowering to *kharif* rice significantly enhanced the yield attributes, yield and zinc content in grain and straw as compared to no application of zinc. Various levels of zinc application to rice crop could not significantly improve the yield attributes and yield of rice fallow greengram. However foliar application of 0.2% $ZnSO_4$ at 25 DAS and flowering significantly increased yield attributes, yield and zinc content in seed and haulm of rice fallow greengram.

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