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Effect of Long-Term use of Inorganic Fertilizers, Organic Manures and Their Combination on Yield Attributes and Yield under Rice-Rice Cropping System

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ABSTRACT

A field experiment entitled "Carbon sequestration and soil health under long term soil fertility management in rice-rice cropping system" was carried out under field conditions during both *kharif* and *rabi* seasons of 2016-2017 and 2017- 2018 at Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station, Maruteru, West Godavari district in the ongoing All India Coordinated Research Project on Long Term Fertilizer Experiment Project. The results reported that the highest grain and straw yield was observed with the application of 100%NPK in combination with $ZnSO_4$ and FYM @ 5t ha^{-1}. It was significantly superior over all other treatments during both the years of study. Dry matter accumulation was higher with the application of 100%NPK in combination with $ZnSO_4$ and FYM @5t ha^{-1}. However, it was on par with that of application of 100% NPK along with $ZnSO_4$ @ 40 kg ha^{-1} and significantly superior over all other treatments during both the years of the study in *kharif* and *rabi*.

Key words: *Grain yield, Inorganics, Organic manures, Rice- rice cropping*

Rice (Oryza sativa L.) is the principal food crop of the world, contributes to about 60% of the world's food. Rice is the major cereal crop feeding two- third of the global population. Rice occupies one-third of the world's crop land planted to cereals and provides 30-60% of the calories consumed by nearly three billion people (Gurra *et al*., 1998). Higher production requirements for the future to meet the demands of growing population need to be achieved, maintaining the soil quality and sustainability of the productivity at the same time.

Rice-rice, the main cropping system in the eastern coast of India, requires heavy amount of plant nutrients that results in decline in net returns per unit area (Anonymous, 2001). Soil fertility and productivity in Godavari delta are likely to be affected due to intensive rice monoculture with imbalanced fertilization under excessive use of irrigation water. A declining trend in the productivity of rice even when grown under adequate application of N, P and K was reported by Nambiar and Abrol (1989). Continuous use of high level of chemical fertilizers had lead to soil degradation problems, which also proved detrimental to soil health.

MATERIALS AND METHODS

A long-term field experiment was initiated in *kharif*, 1989 with rice-rice cropping system at APRRI & RARS, Maruteru, West Godavari. Initial soil properties of the field are given in (Table.1). The experiment was carried out under field conditions during *kharif* and *rabi* seasons of 2016-2017 and 2017- 2018 at Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station, Maruteru, West Godavari district in the ongoing All India Coordinated Research Project on Long Term Fertilizer Experiment Project. Initial nutrient status given in (table1). The treatments consisted of control (T_1), 100 per cent recommended dose of NPK (T_2), 100 per cent recommended dose of NK (T_3) , 100 per cent recommended dose of PK (T_4), 100 per cent recommended dose of NP (T_5), 100 per cent recommended dose of NPK+$ZnSO_4$ @ 40 kg/ ha (T_6), 100 per cent recommended dose of NPK+$ZnSO_4$ @ 40 kg/ ha + FYM @ 5 t ha^{-1}(T_7), 50 per cent recommended dose of NPK (T_8), 50 % NPK + 50 % N through green manures (T_9), 50 % NPK + 50 % N through FYM (T_{10}), 50 % NPK + 25 % N through green manures + 25 % N through FYM (T_{11}) and FYM only @ 10 t/ha (T_{12}). There were twelve treatments laidout in RBD with three replications for both *kharif* and *rabi* seasons in two years of study. Nitrogen was applied through urea in three equal splits (1/3rd basal+1/3rd at tillering+1/3rd at panicle initiation stage). Phosphorus was applied through DAP was used duly taking its N content into account and potassium as muriate of potash (60 % K_2O) and zinc as zinc sulphate ($ZnSO_4.7H_2O$). The entire dose of phosphorus, potassium and zinc were applied as basal. Recommended dose of fertilizer for *kharif* season was 90: 60: 60 N: P_2O_5: K_2O kg ha^{-1} and for *rabi* season it was 180: 90: 60 N: P_2O_5: K_2O kg ha^{-1}. Well decomposed farmyard manure (FYM) and *Calotropis* (green leaf manure) were applied two weeks before transplanting. The experiment on rice – rice sequence as detailed above was repeated on a same site during *kharif* 2016-17 and *rabi* 2017-18, respectively. Popular cultivars of *kharif* rice and *rabi* rice, MTU-1061, MTU-1010 respectively, were used for the study. Data was collected on on yield attributes and yield of both *kharif* and *rabi* rice.

RESULTS AND DISCUSSION

Drymatter production

Dry matter production is considered to be the reliable index of crop growth. The data on the total dry matter production (DMP) of rice are furnished in (Table 2 and 3). In both the years of study, the DMP was increased steadily with the advancement of the crop growth.

Among all the treatments, the treatment T_7 (100% NPK+ $ZnSO_4$ @ 40 kg/ha + FYM @5 t/ha) was recorded highest dry matter production at all the stages of growth over other treatments in both *kharif* and *rabi* seasons. It might be attributed to the addition of FYM along with inorganic fertilizers (RDF) providing better growing conditions to plants by continuous supply of nutrients and improvement of soil properties.

At tillering stage (Table 2 and 3), the highest drymatter production (2386, 4014, 2984 and 4162 kg ha^{-1}, respectively in *kharif*, *rabi* 2016-17 and *kharif*, *rabi* 2017-18) was observed in treatment T_7 (100% RD of NPK+$ZnSO_4$+FYM @ 5 t ha^{-1}) and it was significantly superior over other treatments but however it was on par with treatment T_6 (100% RD of NPK+$ZnSO_4$). Among the inorganic treatments (T_2, T_3, T_4, T_5, T_6 and T_8), the highest drymatter production was observed in T_6 it was significantly superior over T_3, T_4, T_5 and T_8 but however it was on par with T_2 in *kharif* and *rabi* season during both the years of study. The lowest (926, 1207, 994, 1239 kg ha^{-1} in *kharif*, *rabi* 2016-17 and *kharif*, *rabi* 2017-18) drymatter production was observed in control. Among the combined treatments (T_7, T_9, T_{10} and T_{11}), the treatment T_7 was significantly superior over T_9, T_{10}, T_{11}. However the treatments T_9, T_{10}, T_{11} were on par with each other in *rabi* season. Whereas in *kharif* season T_9, T_{10} were on par with each other and significantly superior over T_{11}. Significantly higher drymatter accumulation in fertilizer treated plots might be due to greater solubility and accelerated release of nitrogen and by providing an opportunity for rice to utilize higher quantum of nutrients. Significant increase in growth characters like (tiller number per unit area, plant height due to combined application of organics and RDF might have resulted in increased photosynthesis and production of photosynthates which finally transformed into higher number of panicles per unit area and thereafter higher accumulation of dry matter. Singh *et al.* (2001a) also reported significant improvement in dry matter accumulation of rice with increasing nutrition on account of better growth and development of the plant.

At panicle initiation stage (Table 2 and 3), drymatter production was ranged from 3022 to 6842; 3319 to 7751; 3018 to 6899; 3406 to 7509 kg ha^{-1} respectively in the four seasons of study. The highest drymatter production was observed in T_7 (100 % NPK+ $ZnSO_4$ +FYM) it was significantly superior over other treatments but however it was on par with treatment T_6. The lowest was observed in T_1 (absolute control). Similar results were observed in both the years of study in *kharif* and *rabi*. Among the inorganic treatments the highest drymatter production was observed in T_6 it was significantly superior over all other inorganic treatments (T_2, T_3, T_4, T_5 and T_8) in *kharif* season. Whereas in *rabi* the highest drymatter production was observed in T_6 which was significantly superior over T_3, T_4, T_5 and T_8 but however it was on par with T_2. Adequate Zn levels in soil increased plant height and consequently, the dry matter accumulation (Fageria *et al.,* 2003). The increase in dry matter accumulation due to proper supply of Zn from $ZnSO_4$ was recorded in the present study which was in accordance with the findings of Ghatak *et al.* (2005) and Sunil *et al.*, 2005.

Among the combined treatments T_7, T_9, T_{10} and $T_{11,}$ drymatter production in T_7, which received 100% NPK+ $ZnSO_4$ + FYM was significantly superior to remaining treatments. However the treatments T_9 (50% NPK+ 50 % N through green manures), T_{10} (50 % NPK + 50 % N through FYM) and T_{11} (50 % NPK + 25 % N through green manure + 25 % N through FYM) were on par with each other in *kharif* season. The treatment T_9 and T_{10} were on par with each other and significantly superior over treatmentT_{11} in *rabi* season at panicle initiation stage.

The organic treatments produced the high DMP. The probable reason might be attributed to the continuous slow release of nutrients which might have enabled the leaf area duration to extend, thereby providing an opportunity for plants to increase the photosynthetic rate which could have led to higher accumulation of dry matter. Similar results were obtained by Sangeetha *et al.* (2013).

The lowest drymatter production at all stages of crop growth period was associated in absolute control (T_1). This was significantly inferior to the dry matter produced by all the organic, inorganic and combined organic and inorganic treatments during both the years of investigation.

At harvesting stage, the drymatter production ranged from 6384 to 15984; 9312 to 18085; 6238 to 16359; 9734 to 18396 kg ha^{-1} respectively in *kharif*, *rabi* 2016-17 and *kharif*, *rabi* 2017-18. Significantly highest production of drymatter was observed in T_7

Table 1. Initial properties of the experimental soil before starting of experiment in 1989

Particulars	VI Block
I. Mechanical analysis	
1. Sand (%)	43
2. Silt (%)	26
3. Clay (%)	31
Textural class	Clay loam
Bulk density (Mg m^{-3})	1.37
pH (1:2.5)	7.00
EC (dS m^{-1})	1.09
Organic carbon (%)	0.55
Available N (kg ha^{-1})	300.00
Available P_2O_5 (kg ha^{-1})	17.00
Available K_2O (kg ha^{-1})	384.00
Available Fe (mg kg^{-1})	4.98
Available Mn (mg Kg^{-1})	5.59
Available Cu (mg kg^{-1})	0.53
Available Zn (mg kg^{-1})	0.62
DHA (µg TPF g^{-1} soil Day^{-1})	166.21
Urease activity (µg of NH_4^+- N g^{-1} soil h^{-1})	15.13

Table 2. Effect of long-term use of inorganic fertilizers, organic manures and their combination on drymatter production (kg ha^{-1}) of rice.

Treatments	*Kharif* (2016)			*Rabi* (2017)		
	Tillering	Panicle initiation	Harvest	Tillering	Panicle initiation	Harvest
T_1 Control	926	3022	6384	1207	3319	9312
T_2 100 % RDF	2140	6004	14754	3436	7053	16134
T_3 100% NK	1823	5613	12618	3110	6381	15579
T_4 100% PK	1385	4867	9918	2086	5746	12283
T_5 100% NP	1724	5374	12364	2958	5446	15113
T_6 100 % RDF + $ZnSo_4$ @ 40 kg/ha	2154	6543	15084	3813	7256	17851
T_7 100 % RDF + $ZnSo_4$ @ 40 kg/ha + FYM @ 5t/ha	2386	6842	15984	4014	7751	18085
T_8 50% NPK	1321	4786	11138	2277	5431	13013
T_9 50% NPK + 50 % N Through Green Manures	1902	5676	11938	2779	6553	14533
T_{10} 50% NPK + 50 % N Through FYM	1992	5724	13868	3167	6759	14943
T_{11} 50% NPK + 25 % N Through GM + 25 % N Through FYM	1670	5624	12128	2966	6089	14864
T_{12} FYM only @ 10 t/ha	1625	5004	11418	1807	5881	11736
SEm ±	80	169	414	164	185	516
CD @ 0.05	235	502	1215	480	550	1513
CV (%)	7.5	7.3	8.8	7.1	9.35	10.18

(100 % NPK+ $ZnSO_4$ +FYM) it was significantly superior over other treatments but however it was on par with treatment T_6 and the lowest was observed in T_1 (absolute control). Control plot showed a drastic reduction in the dry matter accumulation due to the depletion of nutrients with continuous cropping without fertilization, which caused reduction in dry matter accumulation (Bharadwaj and Omanwar, 1994). At harvest stage, among the inorganic treatments the highest drymatter production was observed in T_6 which was significantly superior over all other inorganic treatments (T_2, T_3, T_4, T_5 and T_8) in *kharif*, 17 and *rabi*, 17. However the highest drymatter production was observed in T_6 and it was significantly superior to other treatments but however it was on par with T_2 in *kharif*, 16 and *rabi,* 18. The imbalance of nutrients in soil might be the one of the reasons resulting in abridged absorption of nutrients and improper growth of crop. Continuous application of nitrogenous fertilizers alone adversely affected the soil productivity resulting in reduction in dry matter accumulation due to phosphorus becoming the limiting nutrient. Hence, the balanced application of N, P_2O_5 and K_2O is essential to sustain long-term dry matter accumulation (Rajarajan *et al.* 2005).

Recent studies have indicated that Zn also exhibits prominent influence on growth characteristics of rice crop due to its inter-relationship with auxin, an important growth promoter regulating the stem elongation and cell enlargement. Zinc plays a vital role in biosynthesis of various growth promoting hormones and enzymes. Adequate Zn nutrition was also found to have synergistic effect on N uptake, which is a desirable character (Khanda and Dixit, 1996).

Grain yield

The data pertaining to grain yield presented in table 4 and 5 revealed a significant effect of inorganic fertilizers, organic manures and their combined application on rice during both the years of study.

The grain yield of rice ranged from 2834 to 5980; 3654 to 7846; 2784 to 6200; 3562 to 7934 kg ha^{-1} in *kharif* and *rabi* during both the years of study. The highest grain yield was recorded by the treatment T_7 (100% NPK+ $ZnSO_4$ @ 40 kg/ha + FYM @5 t/ha), which was significantly superior over remaining all the treatments in four seasons. The combined use of FYM and chemical fertilizers ought to have favoured translocation of photosynthates to sink (Halevy, 1979).The increase in yield in integrated plots might be due to better and continuous availability of nutrients for plants which ultimately increased the grain yield. A minimum yield was produced in treatment T_1 (Control).

Among the inorganic treatments the highest grain yield was observed in T_6 which was significantly superior over other inorganic treatments (T_2, T_3, T_4, T_5 and T_8) but however it was on par with treatment T_2 in *kharif* season. whereas in *rabi*, the highest grain yield was observed in T_6 and it was significantly superior to all other inorganic treatments. Increase in yield due to $ZnSO_4$ application along with RDF might be attributed to its role in various enzymatic reaction and catalytic effect on growth process and hormone productions and protein synthesis. Application of $ZnSO_4$ favoured the root growth with mobilization of plant nutrients at optimum levels and there by increased grain and straw yield of rice.

The treatment T_7 was significantly superior to treatment T_2 (100 % RDF). Organic manure mobilized the native Zn through chelation and complex formation with organic ligands and thereby making better availability of native Zn which enhanced the zinc use efficiency (ZUE) for higher grain yield (Rattan *et al.*, 1997). Sujathamma *et al.* (2013) reported the superiority of $ZnSO_4$ in improving rice yield in rice-rice cropping system.

Among the treatments T_9, T_{10} and $T_{11,}$ rice grain yield in T_{11}, which received 50% NPK+ 25 % N through FYM and 25 % N through green manures produced 6378 kg ha^{-1} was on par with T_9 (50% NPK+ 50 % N through green manures and T_{10} (50% NPK+ 50% N through FYM) but significantly superior to T_{12} (FYM only 10 t/ha. The treatments T_9 (50 % NPK + 50 % N through green manures), T_{10} (50 % NPK + 50 % N through FYM) and T_{11} (50 % NPK + 25 % N through FYM + 25 % N through green manures) were on par with each other in all the seaons except in *kharif*, 17. The effects of FYM and green manuring were similar and significantly increased the grain yield of rice over control. Paikary *et al.* (2001) obtained significantly higher rice grain yield with sesbania green manuring and minimum with control.

A better supply of phosphorus has been associated with proliferous root growth resulting in enhanced water and nutrient absorption. This high yield was due to the balanced supply of all important nutrients to the plants. Other treatments, such as NP, NK and PK, were lacking at least one major nutrient, i.e., either N, P or K, and thus might had induced a specific nutrient deficiency stress and retarded overall growth of rice and other crops with a concomitant reduction in yield.

The treatment T_{10} (50% NPK+ 50% N through FYM) was on par with treatment T_2 (100 % NPK) in all the four seasons of study and significantly superior over control. Promising grain yields were also observed in 50 % RDF incorporated with FYM during *kharif* and *rabi* seasons. This was due to the fact that organic manure (FYM) acted as the store house of plant nutrients which were readily utilized by the crop.

Table 3. Effect of long-term use of inorganic fertilizers, organic manures and their combination on drymatter production (kg ha^{-1}) of rice

Treatments	*Kharif*			*Rabi* (2018)		
	Tillering	Panicle initiation	Harvest	Tillering	Panicle initiation	Harvest
T_1 Control	994	3018	6238	1239	3406	9734
T_2 100 % RDF	2486	6019	14984	3489	7012	16705
T_3 100% NK	1961	5689	12869	3162	6395	16139
T_4 100% PK	1412	4870	10438	2113	5501	12964
T_5 100% NP	1816	5349	12129	2993	5287	15786
T_6 100 % RDF + $ZnSo_4$ @ 40 kg/ha	2649	6589	15680	3964	7214	17964
T_7 100 % RDF + $ZnSo_4$ @ 40 kg/ha + FYM @ 5t/ha	2984	6899	16359	4162	7509	18396
T_8 50% NPK	1389	4657	11264	2312	5269	13840
T_9 50% NPK + 50 % N Through Green Manures	2170	5698	12629	2784	6602	15629
T_{10} 50% NPK + 50 % N Through FYM	2318	5783	14364	3261	6598	15835
T_{11} 50% NPK + 25 % N Through GM + 25 % N Through FYM	1734	5542	12649	3018	6094	15013
T_{12} FYM only @ 10 t/ha	1694	5017	11813	1896	5596	11896
SEm ±	116	174	467	172	169	558
CD @ 0.05	340	514	1370	503	496	1638
CV (%)	7.3	8.85	9.41	10.36	8.62	7.92

Table 4. Effect of long-term use of inorganic fertilizers, organic manures and their combination on yield (kg ha^{-1}) of rice

Treatments	*Kharif* (2016)			*Rabi*		
	Grain yield	Straw yield	Harvest index	Grain yield	Straw yield	Harvest index
T_1 Control	2834	3150	47.58	3654	4447	45.08
T_2 100 % RDF	5492	6760	46.39	6614	8053	45.08
T_3 100% NK	5165	6202	43.69	6462	7731	42.55
T_4 100% PK	4440	5090	44.84	5109	6211	45.16
T_5 100% NP	5063	6230	44.4	6310	7817	43.58
T_6 100 % RDF + $ZnSO_4$ @ 40 kg/ha	5727	6861	45.52	7383	8422	46.65
T_7 100 % RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	5980	7313	45.01	7846	8976	46.65
T_8 50% NPK	4812	5252	45.39	5549	6760	45.23
T_9 50% NPK + 50 % N Through Green Manures	5192	5907	45.2	6124	7441	45.91
T_{10} 50% NPK + 50 % N Through FYM	5255	6297	45.71	6175	7509	45.26
T_{11} 50% NPK + 25 % N Through GM + 25 % N Through FYM	5113	6177	44.89	6378	7749	46.61
T_{12} FYM only @ 10 t/ha	4938	5437	45.21	4771	5817	45.05
SEm ±	85	153	0.95	157	178	1.02
CD @ 0.05	250	450	NS	460	550	NS
CV (%)	9.5	10.1	8.8	9.3	10.2	8.9

Table 5. Effect of long-term use of inorganic fertilizers, organic manures and their combination on yield ($kg\ ha^{-1}$) of rice

Treatments	Kharif (2017)			Rabi (2018)		
	Grain yield	Straw yield	Harvest index	Grain yield	Straw yield	Harvest index
T1 Control	2784	3123	47.18	3562	4365	44.16
T2 100 % RDF	5623	6524	46.3	6739	8169	45.27
T3 100% NK	4734	6132	43.56	6512	7816	45.49
T4 100% PK	4154	5095	44.92	5086	6193	45.01
T5 100% NP	4674	5834	44.5	6419	7638	45.62
T6 100 % RDF + ZnSO4 @ 40 kg/ha	5867	7081	45.3	7476	8446	46.91
T7 100 % RDF + ZnSO4 @ 40 kg/ha + FYM @ 5t/ha	6200	7486	45.31	7934	9016	46.93
T8 50% NPK	4172	5134	44.87	5416	6634	44.89
T9 50% NPK + 50 % N Through Green Manures	5014	6138	45.03	6489	7839	45.21
T10 50% NPK + 50 % N Through FYM	5421	6384	45.91	6357	7715	45.22
T11 50% NPK + 25 % N Through GM + 25 % N Through FYM	4936	6183	44.39	6483	7886	45.32
T12 FYM only @ 10 t/ha	4512	5532	44.95	4987	5987	45.53
SEm ±	113	137	0.89	155	191	2.12
CD (P: 0.05)	332	401	NS	454	560	NS
CV (%)	9.8	11.4	8.1	8.9	7.5	8.1

Grain yield during *rabi* season was higher than that of *kharif* which might be due to better translocation of photosynthates from source to sink. This was influenced by the favourable conditions (maximum day light hours and temperature), experienced by the crop during reproductive phase.

Straw yield

The data indicated that different nutrient treatments significantly influenced the straw yield of rice in both the years of the study. Straw yield also followed the similar trend as that of grain yield during both the years of the study ranged from 3150 to 7313, 4447 to 8976, 3123 to 7486 and 4365 to 9016 $kg\ ha^{-1}$ during *kharif* and *rabi* first and second year of study, respectively.

The highest straw yield was observed in T_7 treatment (100% NPK+ $ZnSO_4$ @ 40 kg/ha + FYM @5 t/ha) with (7313, 8976, 7486 and 9016 $kg\ ha^{-1}$ in *kharif*, *rabi* 2016-17 and *kharif*, *rabi* 2017-18) and it was significantly superior over all the other treatments and the lowest straw yield (3150, 4447, 3123, 4365 kg ha^{-1} in *kharif*, *rabi* 2016-17 and *kharif*, *rabi* 2017-18 was observed in control (T_1).

Among the inorganic treatments the highest straw yield was observed in T_6 and it was significantly superior over other inorganic treatments (T_3, T_4, T_5 and T_8) but however it was on par with treatment T_2 in *kharif* and *rabi* season during both the years of study.

The treatment T_2 (100 % NPK) was on par with treatment T_{10} (50 % NPK + 50 % N through FYM) in all the seasons except in *kharif,* 2016. Naing *et al.* (2010) reported increased straw yields in rice with the combined application of FYM and inorganic fertilizers. This implies that by combining inorganic fertilizers with FYM farmers could reduce the use of inorganic fertilizers and still increasing their straw yields.

Among the combined treatments T_7, T_9, T_{10} and $T_{11.}$ rice straw yield in T_7, was significantly superior over T_9, T_{10} and $T_{11.}$ The treatment T_{10} which received 50% NPK+ 50 % N through FYM produced 6297, 7509, 6384, 7715 $kg\ ha^{-1}$ was on par with T_9 (50% NPK+ 50 % N through green manures and T_{11} (50% NPK+ 25% N through FYM + 25% N through green manures) but significantly superior to T_{12} (FYM only 10 t/ha). However, in an integrated nutrient management, organics can maintain plant nutrients in the available forms for longer periods due to improved soil organic matter (SOM) and soil physico-chemical and biological characteristics. These results were in conformity with the findings of Aziz *et al.* (2010) with combined application of FYM and chemical fertilizers. Organics with inorganic N supply NH_4 -N to the plant through continuous mineralization of organic N and in turn increase NUE, ultimately giving higher straw yield.

The treatment T_{12} (FYM only 10 t/ha) only the treatment of completely organic in nature was on par with treatment T_8 (50% NPK) in first year of the study. The treatment T_{12} (FYM only 10 t/ha) was significantly superior over treatment T_4 (100% PK) in 2017, *kharif* rice. The treatments T_2 (100% RDF) was on par with treatment T_{10}, which received 50% NPK+ 50 % N through FYM and treatment T_{11} (50% NPK+ 25% N through FYM + 25% N through green manures) in all seasons except in *kharif,* 2016. Organics with inorganic N supply NH_4 -N to the plant through continuous mineralization of organic N and in turn increase NUE, ultimately giving higher straw yield (Chakraborty *et al*., 1988).

Harvest Index

The data on harvest index revealed that, application of inorganic fertilizers, organics and combined application of inorganic fertilizers and orgnic manures did not attain the level of significance on the harvest index (Table 3 and 4) of rice crop during both *kharif* and *rabi* season.

The maximum harvest index across different treatments was recorded by the treatment T_7 (45.89 %) in 2016 *kharif*, whereas, the maximum by the treatment T_{10} (45.91%) in 2017 *kharif* season. In *rabi* rice during both the years of the study the maximum harvest index was observed by treatment T_7 (100% NPK+ $ZnSO_4$ @ 40 kg/ha + FYM @5 t/ha) It might be due to better grain yield with corresponding biological yield. However, harvest index ranged between 43.69 and 45.89 per cent in *kharif* 2016 where as it ranges from 43.58 to 46.65 percent in *Rabi* 17.

The higher harvest indices with the treatments were due to more economic yield caused by more availability of nutrients. (Waseemraja *et al*., 2010). Higher grain yield, straw yield and harvest index might be due to higher yield attributing characters and dry matter accumulation with respect to 100% NPK + FYM application.

CONCLUSION

The higher dry matter production was observed with the application of 100% RDF in combination with ZnSO 4 and FYM @ 5 t ha -1 . However, it was on par with that of application of 100% RDF along with ZnSO 4 @ 40 kg ha -1 during both the years of the study in kharif and rabi. The significantly highest grain and straw yield was observed with the application of 100% RDF
in combination with ZnSO 4 and FYM @ 5t ha -1 and it was significantly superior over other treatments.

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