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Effect of integrated nutrient management on nodulation and yield of soybean

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Abstract
Soyean (*Glycie max* L. Merril) is a very important oil seed and protein rich crop. It has the capacity to fix atmospheric nitrogen through root nodule bacteria in symbiosis with soybean. Most of the farmers grow soybean without fertilizer and also realize the carry over effect of legume crop on the succeeding wheat crop. The concept of integrated nutrient supply involving organic manures and inorganic fertilizers used to sustained agriculture production and maintain soil health as well as produced crop with less expenditure. Keeping the above points in view the present experiment was carried out for two years in 2016 and 2017. A field experiment was carried out at research farm, Deptt. of soil science & Agricultural chemistry, JNKVV, Jabalpur (M.P.) during Kharif seasons. The experiment consisted of eleven treatment combinations (T_1- FYM 6 t ha^{-1} Enriched with PSB & Rhizobium, T_2- FYM 4 t ha^{-1} Enriched with PSB & Rhizobium + Remaining of RDF through chemical fertilizer, T_3- FYM 2 t ha^{-1} Enriched with PSB & Rhizobium + Remaining of RDF through chemical fertilizer, T_4- Vermicompost 2 t ha^{-1} Enriched with PSB & Rhizobium, T_5- Vermicompost 1.5 t ha^{-1} Enriched with PSB & Rhizobium+ Remaining of RDF through chemical fertilizer, T_6- Vermicompost 1.0 t ha^{-1} Enriched with PSB & Rhizobium + Remaining of RDF through chemical fertilizer, T_7-Poultry Manure 2 t ha^{-1}, T_8-Poultry Manure 1.5 t ha^{-1}+ Remaining of RDF through chemical fertilizer, T_9- Poultry Manure 1.0 t ha^{-1}+ Remaining of RDF through chemical fertilizer,T_{10}-100 % of RDF NPK (25:60:40 kg NPK ha^{-1}) and T_{11} Absolute control. Amongst the INM treatments, T_5 (Vermicompost 1.5 t ha^{-1} Enriched with PSB & Rhizobium+ Remaining of RDF through chemical fertilizer) resulted in higher grain and straw yield, maximum number of root nodule formation $plant^{-1}$ as well as their dry weight at every stage of plant growth. At 60 DAS maximum root nodules were 23.9 $plant^{-1}$ as against only 14.4 $plant^{-1}$ under control treatment. Similarly the dry weight of root nodules at 60 DAS was 46.3 mg $plant^{-1}$ as against only 22.3 mg under control treatment.

Keywords: integrated nutrient management, soybean, nodulation and yield

Introduction

Soybean (*Glycine max* L.) is considered as a wonder crop of 21st century which is the top oil seed in the world production. It is an important oil seed crop in addition to source of food, feed and nutrition. (Imkongtoshi and Gohain, 2009) [14]. It is an excellent health food and contains about 44 per cent good quality protein, 20 per cent cholesterol free oil, 20 per cent carbohydrate and 0.69 per cent phosphorus (Gahukar, 1997) [12]. After green revolution chemical fertilizers has been used at a great extent in all the crops which decrease the fertility and profile of the soil. Due to various side effects of chemical fertilizers, use of organic fertilizers is an alternative method for the improvement of crop production and maintenance of soil fertility. In present situations intensive agriculture requires high input of fertilizers and cost of fertilizers increase constantly. Therefore it is necessary to device such improved practices of cultivation which can minimize the cost and also the dependence on chemical fertilizers use of chemical fertilizers no doubt have boosted the crop growth and yield, but to larger extent they have contributed to soil deterioration. Organic manures help to increase biological activity of soil microbes and improve soil structure, water holding capacity and other physico-chemical properties of soil (Devi *et al*. 2013) [10]. FYM supplies all major nutrients necessary for plant growth, as well as micronutrients. Hence, it acts as a mixed fertilizer (Khan *et al*. 2010) [22], (M. Dejene and M. Lemlem, 2012) [18]. Application of Vermicompost is a sustainable technology capable to improve plants growth and yield (Castillo *et al*., 2010) [8]. Poultry manure (PM) is widely used as an organic fertilizer that is effective in improving soil properties and crop production (Dikinya & Mufwanzala, 2010) [11]. Integration of organic and inorganic sources of nutrients along with biofertilizers is found to give higher productivity and monetary returns in soybean (Bhattacharyya *et al*., 2008) [7].

Material and Methods

The experiment was conducted during rainy seasons of 2016 and 2017 at the research field JNKV, Jabalpur; Madhya Pradesh. The experiment was laid out in Randomized Block Design (RBD) with three replications. There were eleven treatments with following details. T_1- FYM 6 t ha^{-1} Enriched with PSB & Rhizobium, T_2- FYM 4 t ha^{-1} Enriched with PSB & Rhizobium + Remaining of RDF through chemical fertilizer, T_3- FYM 2 t ha^{-1} Enriched with PSB & Rhizobium + Remaining of RDF through chemical fertilizer, T_4- Vermicompost 2 t ha^{-1} Enriched with PSB & Rhizobium, T_5- Vermicompost 1.5 t ha^{-1} Enriched with PSB & Rhizobium + Remaining of RDF through chemical fertilizer, T_6- Vermicompost 1 t ha^{-1} Enriched with PSB & Rhizobium + Remaining of RDF through chemical fertilizer, T_7- Poultry Manure 2 t ha^{-1}, T_8- Poultry Manure 1.5 t ha^{-1} + Remaining of RDF through chemical fertilizer, T_9- Poultry Manure 1 t ha^{-1} + Remaining of RDF through chemical fertilizer, T_{10}- 100 % of RDF NPK (25:60:40 kg NPK ha^{-1}) and T_{11}- Absolute control.

Soyean variety JS-9752 was sown @ 75 kg seed ha^{-1} in rows 45 cm. The recommended dose of fertilizer N:P_2O_5:K_2O was applied @ 25:60:40 kg ha^{-1} for soybean crop. Nitrogen, Phosphorus and Potassium was applied through chemical fertilizer through urea, SSP and muriate of potash.

Nutrient sources

Application of FYM, Poultry manure and Vermicompost

Well decomposed farm yard manure, poultry manure and vermicompost were applied as per treatment at the time of sowing and thoroughly incorporated in soil with the help of spade.

Chemical analysis of FYM, Vermicompost and Poultry manure

A representative homogeneous sample each of the above manures was taken and analyzed for available N, P_2O_5 and K_2O content. The contents are given in (table 1).

Table 1: Composition of nutrients of FYM, Vermicompost and poultry manure

INM Component	Composition (%)					
	2016			2017		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Farm Yard Manure (FYM)	0.48	0.18	0.45	0.49	0.18	0.46
Vermicompost (VC)	1.50	0.62	1.02	1.52	0.63	1.04
Poultry Manure (PM)	1.80	1.60	1.40	1.82	1.64	1.42

Table 2: Applied doses of nutrients from manures & fertilizers

S. N.	Treatments details	Kharif 2016					
		Manures Content			Fertilizer Content		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
T_1	FYM 6 t ha^{-1} Enriched PSB & Rhizobium	28.8	10.8	27.0	_	_	_
T_2	FYM 4 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF	19.2	7.2	18.0	5.8	52.8	22.0
T_3	FYM 2 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF	9.6	3.6	9.0	15.4	56.4	31.0
T_4	VC 2 t ha^{-1} Enriched PSB & Rhizobium	30.0	12.4	20.4	_	_	_
T_5	VC 1.5 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF	22.5	9.3	15.3	2.5	51.0	25.0
T_6	VC 1 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF	15.0	6.2	10.2	10.0	54.0	30.0
T_7	PM 2 t ha^{-1}	36.0	32.0	28.0	_	_	_
T_8	PM 1.5 t ha^{-1} + RRDFCF	27.0	24.0	21.0	_	36.0	19.0
T_9	PM 1 t ha^{-1} + RRDFCF	18.0	16.0	14.0	7.0	44.0	26.0
T_{10}	100 % of RDF NPK (25:60:40 kg NPK ha^{-1})	_	_	_	25.0	60.0	40.0
T_{11}	Control	_	_	_	_	_	_
S. N.	Treatments details	Kharif 2017					
		Manures Content			Fertilizer Content		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
T_1	FYM 6 t ha^{-1} Enriched PSB & Rhizobium	29.4	10.8	27.6	_	_	_
T_2	FYM 4 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF	19.6	7.2	18.4	5.4	52.8	21.6
T_3	FYM 2 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF	9.8	3.6	9.2	15.2	56.4	30.8
T_4	VC 2 t ha^{-1} Enriched PSB & Rhizobium	30.4	12.6	20.8	_	_	_
T_5	VC 1.5 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF	22.8	9.45	15.6	2.2	50.55	24.4
T_6	VC 1 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF	15.2	6.3	10.4	9.8	53.7	29.6
T_7	PM 2 t ha^{-1}	36.4	32.8	28.4	_	_	_
T_8	PM 1.5 t ha^{-1} + RRDFCF	27.3	24.6	21.3	_	35.4	18.7
T_9	PM 1 t ha^{-1} + RRDFCF	18.2	16.4	14.2	6.8	43.6	25.8
T_{10}	100 % of RDF NPK (25:60:40 kg NPK ha^{-1})	_	_	_	25.0	60.0	40.0
T_{11}	Control	_	_	_	_	_	_

RRDFCF=Remaining of RDF through Chemical fertilizer

Number and weight of root-nodules plant^{-1}

Five plants from each plot were taken to estimate soybean nodulation (number of nodule, nodule and dry weight of nodule) and dry weight of nodule was recorded in mg, dried in hot air oven at 60 ^{0}C for 3-4 days (till constant weight) at 30, 45 and 60 days of sowing (DAS).The crop was harvested plot wise and yields of seed and Stover were recorded.

Results and Discussion

Number of root nodules plant^{-1}

The formation of root nodules per plant was influenced up to significant extent due to different INM treatments applied to soybean (Table 3.1). The root nodules increased up to 45 DAS and then decreased in all the treatments. The treatment T_5 having VC 1.5 t ha^{-1} Enriched PSB & Rhizobium +

RRDFCF performed the best in the formation of maximum number of root nodules plant^{-1} at 30,45 and 60 DAS stages of plant growth. The maximum root nodules at 30 DAS were 19.8 plant^{-1} at 60 DAS 30.0 plant^{-1} and 60 DAS 23.9 plant^{-1}. The second best treatment was T_2 having FYM 4 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF 19.5, 28.9 and 23.0 plant^{-1} at 30, 45 and 60 DAS, respectively. The third best treatment was T_6 having VC 1.0 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF and this was followed by T_3 (FYM 2 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF) and T_4 (VC 2 t ha^{-1} Enriched PSB & Rhizobium). The significantly lowest root-nodules were observed under the control treatment i.e. 13.9, 19.1 and 14.4 root- nodules plant^{-1} at 30, 45 and 60 DAS stages, respectively.

Dry weight of root nodules plant^{-1}

The periodically dry weight of root nodules was also recorded treatment-wise and after statistical analysis the data are presented in (Table 3.2) it is apparent that this parameter was influenced up to significant extent due to applied INM treatment. Accordingly, the treatment T_5 (VC 1.5 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF) resulted in maximum dry weight of root-nodules at every stage of plant growth. Thus the highest dry weight at 30 DAS was 16.0 mg plant^{-1}, at 45 DAS 60.1 mg plant^{-1} and at 60 DAS 46.3 mg dry weight of root nodules plant^{-1}. The second best INM treatment was T_2 (FYM 4 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF) which recorded 15.6, 58.1 and 42.8 mg dry weight at 30, 45 and 60 DAS, respectively. The third best treatment was T_6 (VC 1.0 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF) and then T_3 (FYM 2 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF) and T_4 (VC 2 t ha^{-1} Enriched PSB & Rhizobium). The significantly minimum dry weight of root nodules (only 9.7, 27.8 and 22.3 mg at the respective stages) was noted in case of control (T_{11}) treatment. The treatments T_7, T_8 and T_9 also recorded this parameter almost equally in the lowest range.

Productivity parameters

The critical observation of the data as presented in (Table 3.3) indicate that the grain and Stover yield of soybean were influenced significantly due to different INM treatments. Out of the eleven INM treatments, T_5 (VC 1.5 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF) resulted in highest grain yield (1923 kg ha^{-1}) Stover yield (3192 kg ha^{-1}). This was closely followed by T_2 (FYM 4 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF) where the grain yield was 1895 kg ha^{-1} and Stover yield 3084 kg ha^{-1}. The third position attained by T_8 (PM 1.5 t ha^{-1} + RRDFCF) where the grain yield was 1852 kg ha^{-1} and Stover yield 2868 kg ha^{-1}. The fourth best INM treatment was T_{10} having 100 NPK. The significantly lowest grain yield (1197 kg ha^{-1}) and Stover yield (2147 kg ha^{-1}) were recorded in case of control treatment.

Root nodulation

Root nodulation studies at 30, 45 and 60 DAS growth stages indicated that the different INM treatments brought about significant changes in the formation of root nodules plant^{-1} as well as on their dry weight. Amongst the INM treatments, T_5 (VC 1.5 t ha^{-1} Enriched PSB & Rhizobium + RRDFCF) resulted in maximum number of root nodule formation plant^{-1} as well as their dry weightplant^{-1} at every stage of plant growth. At 60 DAS maximum root nodules were 23.9 plant^{-1} as against only 14.4 plant^{-1} under control treatment. Similarly the dry weight of root nodules at 60 DAS was 46.3 mg plant^{-1} as against only 22.3 mg under control treatment. The second and third best treatments were T_2 (FYM 4 t ha^{-1} Enriched with PSB & Rhizobium + RRDFCF) and then T_6 (Vermicompost 1 t ha^{-1} Enriched with PSB & Rhizobium + RRDFCF) respectively. The maximum increase in root-nodules and their dry weight plant^{-1} in treatment T_5, T_2 and T_6 may be ascribed to the adequate availability of multinutrient and increased proliferation of nitrogen fixing as well as phosphorus-solubilizing bacteria in the rhizosphere (root-zone) and their increased activity. These results are in conformity with those of (Patel and Puraji, 2003) [25], (Bandhyopadhyay *et al.*, 2004) [5], (More *et al.*, 2008) [21], (Alam *et al.*, 2009) [3], (Lone *et al.*, 2009) [17], (Mohod *et al.*, 2010) [20], (Gunjal *et al.*, 2010) [13], (Ahsan *et al*., 2012) [1].

Productivity of soybean

The data summarized in (table 3.3) indicate that the grain and stover yield (1923 and 3192 kg ha^{-1}, respectively) were found significantly higher in case of T_5 (Vermicompost 1.5 t ha^{-1} Enriched with PSB & Rhizobium + RRDFCF) as compared to most of the other INM treatments. However this was closely followed by T_2 (1895 and 3084 kg ha^{-1}), T_8 (1852 and 2868 kg ha^{-1} grain and stover respectively).On the other hand, the significantly lowest yield (1197 kg grain and 2147 kg stover) was secured from the control treatment. This might be owing to maximum growth parameters and consequently yield-attributes as a result of higher rate of photosynthesis which is always associated with higher productivity (Sanwal *et al.*, 2007) [27]. The higher yield response due to T_5, T_2 and T_8 INM treatments having higher amount of FYM and vermicomposting is ascribed to improvement in physico-chemical and biological properties of the soil and nutrient use efficiency resulting in better supply of multi plant-nutrients led to good crop growth and yields. The significant variation in grain yield response to different INM treatments (FYM or VC with biofertilizers and NPK) might be due to variations in their nutrient composition, decomposition of organic residues, carbon: nitrogen ratio, nutrient release pattern, climate and soil characteristics. The present results are in accordance with the findings of (Behera *et al.*, 2007) [6], (Mahesh Babu *et al.*,2008) [19], (Reddy *et al.*, 2009) [26], (Akbari *et al.*,2010) [2], (Dashora and Solanki, 2010) [9], (Palve *et al.*, 2011) [24], (Bachhav *et al.*2012) [4], (Singh *et al.*,2012) [29], (Jain, (2015) [16], (Sheikh *et al.*, 2015) [28], (Yagoub *et al.* 2015) [32], (Vitnor *et al.*, 2015) [31], (Jaga and Sharma, 2015) [15], (Nagar *et al.*, 2016) [23] and (Sutrismo, 2017) [30].

Conclusion

The findings of the two years of experiment on soybean allude that amongst the INM treatments, application of T_5 (Vermicompost 1.5 t ha^{-1} Enriched with PSB & Rhizobium+ Remaining of RDF through chemical fertilizer) recorded almost significantly higher number of root nodules, dry weight of root nodules and grain and stover yield.

Table 3.1: Root nodules per plant at different intervals of soybean as influenced by integrated nutrient management treatments (Pooled for 2 years)

Treatments	Number of nodule plant^{-1}		
	30 DAS	45 DAS	60 DAS
FYM 6 t ha^{-1} Enriched with PSB & Rhizobium	17.4	26.0	20.2
FYM 4 t ha^{-1} Enriched with PSB & Rhizobium + RRDFCF	19.5	28.9	23.0
FYM 2 t ha^{-1} Enriched with PSB & Rhizobium + RRDFCF	18.8	27.6	21.5
VC 2 t ha^{-1} Enriched with PSB & Rhizobium	17.9	26.8	21.2
VC 1.5 t ha^{-1} Enriched with PSB & Rhizobium + RRDFCF	19.8	30.0	23.9
VC 1 t ha^{-1} Enriched with PSB & Rhizobium + RRDFCF	19.1	28.2	22.6
PM 2 t ha^{-1}	14.5	20.4	17.2
PM 1.5 t ha^{-1} + RRDFCF	14.8	21.0	18.1
PM 1 t ha^{-1} + RRDFCF	15.2	22.5	18.5
100 % of RDF NPK (25:60:40 kg NPK ha^{-1})	15.5	22.9	18.8
Control	13.9	19.1	14.4
SEm (±)	1.39	1.83	1.70
CD (P=0.05)	4.09	5.38	5.00

RRDFCF=Remaining of RDF through Chemical fertilizer

Table 3.2: Dry weight root nodules per plant at different intervals of soybean as influenced by integrated nutrient management treatments (Pooled for 2 years)

Treatments	Dry weight of nodule plant^{-1} (mg)		
	30 DAS	45 DAS	60 DAS
FYM 6 t ha^{-1} Enriched with PSB & Rhizobium	11.6	47.4	31.3
FYM 4 t ha^{-1} Enriched with PSB & Rhizobium + RRDFCF	15.6	58.1	42.8
FYM 2 t ha^{-1} Enriched with PSB & Rhizobium + RRDFCF	13.7	51.2	39.0
VC 2 t ha^{-1} Enriched with PSB & Rhizobium	13.5	51.0	34.3
VC 1.5 t ha^{-1} Enriched with PSB & Rhizobium + RRDFCF	16.0	60.1	46.3
VC 1 t ha^{-1} Enriched with PSB & Rhizobium + RRDFCF	15.2	54.0	40.8
PM 2 t ha^{-1}	9.8	35.1	24.1
PM 1.5 t ha^{-1} + RRDFCF	9.8	40.1	25.8
PM 1 t ha^{-1} + RRDFCF	10.1	41.9	26.3
100 % of RDF NPK (25:60:40 kg NPK ha^{-1})	11.0	44.0	28.9
Control	9.7	27.8	22.3
SEm (±)	0.98	3.82	2.67
CD (P=0.05)	2.88	11.26	7.85

RRDFCF=Remaining of RDF through Chemical fertilizer

Table 3.3: Effect of integrated nutrient management on seed yield and Stover yield (Pooled for 2 years)

Treatments	Grain Yield (Kg ha^{-1})	Stover Yield (Kg ha^{-1})
FYM 6 t ha^{-1} Enriched with PSB & Rhizobium	1457	2355
FYM 4 t ha^{-1} Enriched with PSB & Rhizobium + RRDFCF	1895	3084
FYM 2 t ha^{-1} Enriched with PSB & Rhizobium + RRDFCF	1516	2592
VC 2 t ha^{-1} Enriched with PSB & Rhizobium	1476	2471
VC 1.5 t ha^{-1} Enriched with PSB & Rhizobium + RRDFCF	1923	3192
VC 1 t ha^{-1} Enriched with PSB & Rhizobium + RRDFCF	1603	2637
PM 2 t ha^{-1}	1432	2274
PM 1.5 t ha^{-1} + RRDFCF	1852	2868
PM 1 t ha^{-1} + RRDFCF	1490	2510
100 % of RDF NPK (25:60:40 kg NPK ha^{-1})	1799	2824
Control	1197	2147
SEm (±)	131	215
CD (P=0.05)	385	636

RRDFCF=Remaining of RDF through Chemical fertilizer

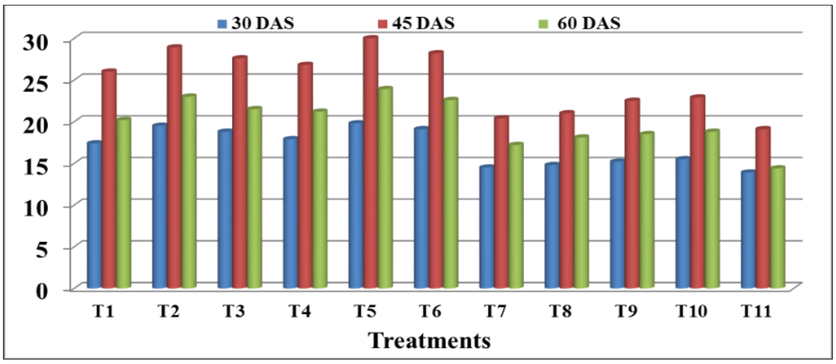

Fig 1.1: Number of root nodules plant^{-1}

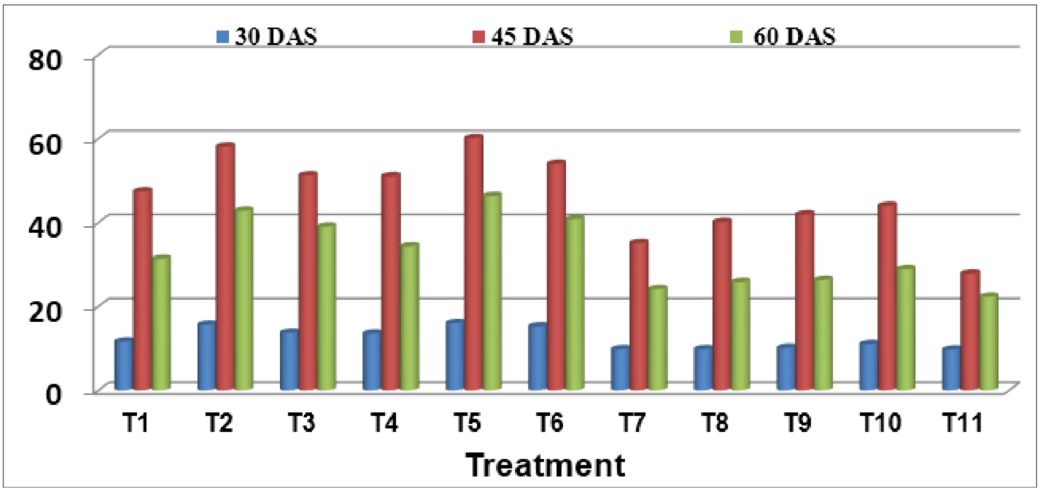

Fig 1.2: Dry weight of root nodules per plant (mg-1)

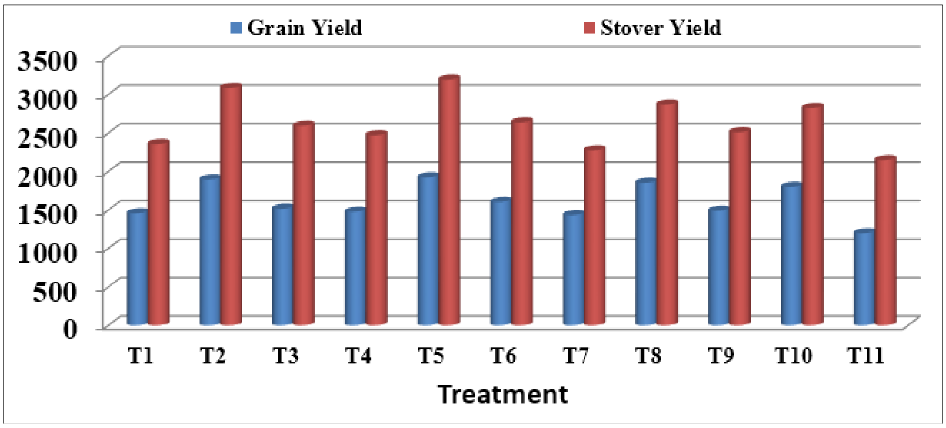

Fig 1.3: Grain and Stover yield Kg ha^{-1}

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