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Palak Singh
Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur, Chhattisgarh, India

HP Agrawal
Principal Scientist, Department of Agronomy, B.T.C. CARS, Bilaspur, Chhattisgarh, India

JR Patel
Principal Scientist, Department of Agronomy, B.T.C. CARS, Bilaspur, Chhattisgarh, India

PK Keshry
Assistant Professor, Department of Soil science, B.T.C. CARS, Bilaspur, Chhattisgarh, India

NK Chaure
Principal Scientist, Department of Agricultural Statistics, B.T.C. CARS, Bilaspur, Chhattisgarh, India

AP Agrawal
Principal Scientist and HOS of Genetics and Plant Breeding, B.T.C. CARS, Bilaspur, Chhattisgarh, India

Geet Sharma
Scientist Department of Agronomy, B.T.C. CARS, Bilaspur, Chhattisgarh, India

Chanchala Rani Patel
Farm manager, Department of Agronomy, KVK, Bilaspur, Chhattisgarh, India

Deepika Rawate
M.sc. (Agriculture), Department of Agronomy, B.T.C. CARS, Bilaspur, Chhattisgarh, India

Hetram
M.sc. (Agriculture), Department of Agronomy, B.T.C. CARS, Bilaspur, Chhattisgarh, India

M Mitasha
M.sc. (Agriculture), Department of Agronomy, B.T.C. CARS, Bilaspur, Chhattisgarh, India

Corresponding Author:
Palak Singh
Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur, Chhattisgarh, India

"Performance of Integrated nutrient management on growth and yield of horsegram (*Macrotyloma uniflorum* L.) in Chhattisgarh plain"

Palak Singh, HP Agrawal, JR Patel, PK Keshry, NK Chaure, AP Agrawal, Geet Sharma, Chanchala Rani Patel, Deepika Rawate, Hetram and M Mitasha

Abstract
The present investigation entitled "Performance of Integrated nutrient management on growth and yield of horsegram (*Macrotyloma uniflorum* L.) in Chhattisgarh plain" was conducted at the Agricultural Research Farm of Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur, during post-kharif season of 2021-2022. The experiment was laid down in randomized block design (RBD) with 11 treatments and three replications including organic, inorganic nutrients and recommended dose of fertilizer (RDF) 20:40:20 NPK kg ha^{-1} with taking of horsegram variety "Chhattisgarh Kulthi-2". The investigation result recorded that treatment T_2 (125% RDF) has achieved significantly maximum growth and yield attributes *viz*., plant height (cm), number of primary branches plant^{-1}, dry matter accumulation (g plant^{-1}), number of pods plant^{-1} (30.63), pod length (4.76 cm), number of seeds pod^{-1} (6.40), test weight (29.97 g) and treatment T_{11} (Control) has achieved lowest growth and yield attributes. The highest seed yield (915.30 Kg ha^{-1}) and straw yield (1340.00 Kg ha^{-1}) was also recorded in treatment T_2 but it was at par with treatment T_6 (100% RDF + *Rhizobium* culture + PSB), T_4 (100% RDF + *Rhizobium* culture), T_3 (100 RDF + Vermicompost @ 0.5 t ha^{-1}), T_5 (100% RDF + PSB) and T_1(100% RDF) and the highest benefit cost ratio (1.70) was recorded under treatment T_2.

Keywords: Integrated nutrient management, *Rhizobium* culture, vermicompost, yield attributes

Introduction
Horsegram (*Macrotyloma uniflorum* L.) is a hardy pulse crop of semi-arid tropics that has been poorly studied despite its current and historical importance to the diet of a large part of population in India, there are entrenched biases against horsegram, as it is considered a low status food of the poor particularly in southern India (Kadam *et al.*, 1985) [6]. It is an annual herb, growing to a height of 30-40 cm (Neelam *et al.*, 2014) [9]. Horsegram is a post *kharif* crop and commonly known as kulthi, hurali or madras gram. Horsegram belongs to pulse family fabaceae. It is an annual herb, growing to a height of 30-40 cm (Neelam *et al.*, 2014) [9]. Horsegram can tolerate a wide range of climate and soil conditions (Kachroo *et al.*, 1970) [5]. In India horsegram occupies an area of 460.40 thousand ha with a production of 117 thousand tons with an average national productivity of 38.2 kg ha^{-1} (Anonymous 2017-18) [1]. Horsegram is an important pulse crop mostly grown in Karnataka, Odisha, Chhattisgarh, Andhra Pradesh, Tamil Nadu and Maharashtra which together account for 89.23% and 86.10% production. In India, horsegram is cultivated as a pulse crop contributing about 0.33% of total food grain production (Ramteke *et al*., 2016) [10].

In Chhattisgarh horsegram is grown widely, in Chhattisgarh horsegram occupies an area of 40.15 (000 ha) with a production of 15.20 (000 tonnes) and average productivity of 379 kg ha^{-1} (Anonymous 2018-19) [2]. In Chhattisgarh horsegram grown on the district of Jagdalpur, Kanker, Korba, Sarguja and Jashpur which on adding contributes about 69.74% area and 76.61% production. However the production of horsegram is highest in Janjgir (388kg ha^{-1}).

Integrated Nutrient management is the combined application of chemical fertilizers along with organic resource materials like organic manures, green manures, bio-fertilizers and other organic decomposable materials for crop production. The basic concept of integrated nutrient management (INM) is the adjustment of plant nutrients supply to an optimum level for sustaining the desired crop productivity. It involves proper combination of chemical fertilizers, organic manure crop residues, N2 – fixing crops like pulses such as greengram, blackgram,

redgram, other pulses and oilseeds such as soyabean, bio-fertilizers suitable to the system of land use and ecological, social and economic conditions.

Material and Methods

The experiment was conducted at the Agricultural Research Farm of Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur (Chhattisgarh) in kharif season 2021. The Research Farm is situated at 22.09˚N latitude, 82.15˚E longitude and at an altitude of 298 m above mean sea level. The region falls under the Eastern plateau and hill region (Agro-climatic zone-VII) of India. Chhattisgarh state is classified into three agro-climatic zones, of which Bilaspur falls under the Chhattisgarh plains zone of the state. The experimental field was well drained with uniform topography. Agro-climatically, the experimental site comes into a dry, moist, sub-humid area. The test variety is Chhattisgarh Kulthi -2. The experiment was laid out in Randomized block design with 11 treatments and three replications, the treatment comprised of T_1 (100% RDF), T_2 (125% RDF), T_3 (100% RDF + Vermicompost @ 0.5 t ha^{-1}), T_4 (100% RDF + *Rhizobium* culture), T_5 (100% RDF + PSB), T_6 (100% RDF + *Rhizobium* culture + PSB), T_7 (75% RDF + Vermicompost @ 1t ha^{-1}), T_8 (75% RDF + *Rhizobium culture*), T_9 (75% RDF + PSB), T_{10} (75% RDF +*Rhizobium* culture+ PSB), T_{11} (Control). The recommended dose of fertilizer is 20: 40:20 NPK Kg ha^{-1}. Different growth and yield attributes *viz*., plant height (cm), number of primary branches $plant^{-1}$, dry matter accumulation (g $plant^{-1}$), number of pods $plant^{-1}$, pod length, number of seeds pod^{-1}, test weight straw yield (Kg ha^{-1}) was recorded at different crop growth stages.

Note: RDF (recommended dose of fertilizer), PSB (phosphate solubilizing bacteria)

Result and Discussion

The result from the experiment is as followed

Plant population (m^{-2})

At 25 DAS it was observed that the highest number of plant population was recorded in T_2 (125% RDF), is (40.26 plant m^{-2}) followed by T_6 (100% RDF + *Rhizobium* culture + PSB) is (40.18 plant m^{-2}). The lowest number of plant population recorded is (38.96 plant m^2) in treatment T_{11} (control), similar trend was followed at harvest.

Plant height (cm)

The data shows that significant influence on plant height of the 11 treatments at all stages of growth *Viz*., 25, 50, 75 DAS and at harvest. At 25 DAS, the data varies in plant height were found significant and treatment T_2 (125% RDF) recorded significantly higher plant height (20.56 cm), at par with treatment T_6 (100% RDF + *Rhizobium* culture + PSB) is (20.54 cm), treatment T_4 (100% RDF + *Rhizobium* culture) is (20.51 cm), treatment T_3 (100% RDF + Vermicompost @ 0.5 t ha^{-1}) is (20.50cm), treatment T_5 (100% RDF + PSB) is (20.48 cm) and T_1 (100% RDF) is (20.45 cm). The lowest plant height (13.45 cm) is recorded in treatment T_{11} (control), similar trend was followed at 50, 75 and at harvest. This result was conformity with Barcchiya *et al*. (2017) [3].

Number of primary branches $plant^{-1}$

Number of primary branches $plant^{-1}$ was recorded at 25, 50, 75 DAS and at harvest and it was revealed that at 25 DAS treatment T_2 (125% RDF) is (3.09) has highest number of primary branches $plant^{-1}$ followed by T_6 (100% RDF + *Rhizobium* culture +PSB) is (2.99) $plant^{-1}$, T_4 (100% RDF + *Rhizobium* culture) is (2.90) $plant^{-1}$, T_3 (100% RDF + Vermicompost @ 0.5 t ha^{-1}) is (2.82) $plant^{-1}$, T_5 (100% RDF +PSB) is (2.72) $plant^{-1}$,and T_1 (100% RDF) is (2.68) $plant^{-1}$. The lowest number of primary branches $plant^{-1}$ was recorded for treatment T_{11} (Control) is (1.25), it was seen that integrated nutrient management has notably affected the number of primary branches $plant^{-1}$, similar trend was followed at 50, 75 and at harvest. This result was conformity with (Kumari *et al.* (2012) [8].

Dry matter accumulation (g $plant^{-1}$)

Dry matter accumulation of the crop was significantly affected by integrated nutrient management and it was at recorded at 25, 50, 75 DAS and at harvest. At 25 DAS the highest dry matter accumulation (g $plant^{-1}$) was recorded by treatment T_2 (100% RDF) is (0.50) at par with treatment T_6 (100% RDF + *Rhizobium* culture + PSB) is (0.49), treatment T_4 (100% RDF + *Rhizobium* culture) is (0.48), treatment T_3 (100% RDF+ Vermicompost@ 0.5 t ha^{-1}) is (0.47), treatment T_5 (100% RDF + PSB) is (0.45),treatment T_1 (100% RDF) is (0.45) and the lowest was recorded at treatment T_{11} (control) is (0.37), similar trend was followed at 50, 75 and at harvest.

Crop growth rate (g $plant^{-1}$ day^{-1})

Crop growth rate was recorded at 25-50 DAS, 50-75 DAS, 75 DAS - at harvest. At 25-50 DAS the highest crop growth rate was recorded in treatment T_2 (125% RDF) is (0.141 g $plant^{-1}$ day^{-1}) and lowest was recorded in treatment T_{11} (control) is (0.130 g $plant^{-1}$ day^{-1}), similar trend was followed at 25-50 DAS, 50-75 DAS, 75 DAS - at harvest.

Relative growth rate (g g^{-1} day^{-1})

Relative growth rate was recorded at 25-50 DAS, 50-75 DAS and 75 DAS- at harvest. At 25 – 50 DAS the highest relative growth rate was recorded in treatment T_2(125% RDF) is (0.0785 g $g^{-1}day^{-1}$)and lowest was recorded in treatment T_{11} (control) is (0. 0746 g g^{-1} day^{-1}),similar trend was followed at 25-50 DAS, 50-75 DAS, 75 DAS - at harvest.

Table 1: Effect of integrated nutrient management on plant population (m^{-2}) of horsegram

Treatments		Plantpopulation	
		25 Das	At Harvest
T_1	100% RDF	39.85	37.91
T_2	125% RDF	40.26	38.45
T_3	100% RDF + vermicompost(0.5 t ha^{-1})	40.05	38.19
T_4	100%RDF + *Rhizobium* culture	40.11	38.22
T_5	100% RDF + PSB	39.96	38.07
T_6	100% RDF + *Rhizobium* culture + PSB	40.18	38.37
T_7	75%RDF + vermicompost(1 t ha^{-1})	39.41	37.55
T_8	75% RDF + *Rhizobium* culture	39.59	37.67
T_9	75% RDF + PSB	39.29	37.41
T_{10}	75% RDF + *Rhizobium* culture + PSB	39.73	37.74
T_{11}	Control	38.96	37.15
SEm ±		0.88	0.92
CD (P=0.05)		NS	NS

Table 2: Effect of integrated nutrient management on plantheight (cm) of horsegram

Treatments		Plant height			
		25 DAS	50 DAS	75 DAS	At harvest
T_1	100% RDF	20.45	43.93	53.89	53.00
T_2	125%RDF	20.56	46.26	56.01	55.51
T_3	100% RDF + vermicompost(0.5 t ha^{-1})	20.50	44.57	54.31	53.81
T_4	100% RDF + *Rhizobium* culture	20.51	45.02	54.76	54.26
T_5	100% RDF + PSB	20.48	43.97	54.00	53.21
T_6	100% RDF + *Rhizobium* culture + PSB	20.54	45.74	55.49	54.99
T_7	75% RDF + vermicompost(1 t ha^{-1})	16.92	39.66	49.15	48.70
T_8	75% RDF + *Rhizobium* culture	16.95	40.09	49.20	48.77
T_9	75% RDF + PSB	16.88	39.47	49.10	48.67
T_{10}	75% RDF + *Rhizobium* culture + PSB	17.00	40.12	49.30	48.80
T_{11}	Control	13.45	35.24	44.54	44.44
SEm±		1.12	1.27	1.51	1.29
CD (P=0.05)		3.30	3.77	4.47	3.81

Table 3: Effect of integrated nutrient management on number of primary branches $plant^{-1}$of horsegram

Treatments		No. of primary branches			
		25 DAS	50 DAS	75 DAS	at harvest
T_1	100% RDF	2.68	4.98	6.03	6.45
T_2	125% RDF	3.09	5.14	6.26	6.63
T_3	100% RDF+ vermicompost(0.5 t ha^{-1})	2.82	5.06	6.12	6.53
T_4	100% RDF + *Rhizobium* culture	2.90	5.08	6.15	6.58
T_5	100% RDF + PSB	2.72	5.00	6.05	6.49
T_6	100% RDF+ *Rhizobium* culture + PSB	2.99	5.12	6.20	6.60
T_7	75% RDF + vermicompost(1 t ha^{-1})	1.73	4.24	5.45	5.83
T_8	75% RDF + *Rhizobium* culture	1.80	4.28	5.48	5.85
T_9	75% RDF + PSB	1.70	4.20	5.40	5.80
T_{10}	75% RDF + *Rhizobium* culture + PSB	2.00	4.30	5.50	5.88
T_{11}	control	1.25	3.60	4.86	5.23
SEm ±		0.14	0.15	0.17	0.18
CD (P=0.05)		0.43	0.45	0.51	0.54

Table 4: Effect of integrated nutrient management on dry matter accumulation (g $plant^{-1}$) of horsegram

Treatments		Dry matter accumulation			
		25 DAS	50 DAS	75 DAS	At harvest
T_1	100% RDF	0.45	4.43	7.63	9.31
T_2	125% RDF	0.50	4.80	8.22	9.89
T_3	100% RDF + vermicompost(0.5 t ha^{-1})	0.47	4.55	7.82	9.48
T_4	100% RDF + *Rhizobium* culture	0.48	4.62	7.97	9.56
T_5	100% RDF + PSB	0.45	4.49	7.70	9.42
T_6	100% RDF + *Rhizobium* culture + PSB	0.49	4.69	7.99	9.81
T_7	75% RDF + vermicompost(1 t ha^{-1})	0.42	4.27	7.32	8.82
T_8	75% RDF + *Rhizobium* culture	0.42	4.31	7.39	8.96
T_9	75% RDF + PSB	0.41	4.23	7.27	8.73
T_{10}	75% RDF + *Rhizobium* culture + PSB	0.43	4.35	7.47	9.06
T_{11}	Control	0.37	4.02	7.00	8.42
SEm ±		0.016	0.112	0.118	0.200
CD (P=0.05)		0.047	0.331	0.347	0.591

Table 5: Effect of integrated nutrient management on crop growth rate (g $plant^{-1}$ day^{-1}) of horsegram

Treatments		Crop growth rate		
		25-50 DAS	50-75 DAS	75 DAS -at harvest
T_1	100% RDF	0.134	0.105	0.055
T_2	125% RDF	0.141	0.116	0.063
T_3	100% RDF + vermicompost(0.5 t ha^{-1})	0.136	0.109	0.058
T_4	100% RDF + *Rhizobium* culture	0.138	0.112	0.060
T_5	100% RDF + PSB	0.135	0.107	0.056
T_6	100% RDF + *Rhizobium* culture + PSB	0.138	0.115	0.061
T_7	75% RDF + vermicompost(1 t ha^{-1})	0.131	0.099	0.050
T_8	75% RDF + *Rhizobium* culture	0.132	0.101	0.052
T_9	75% RDF + PSB	0.131	0.097	0.049
T_{10}	75% RDF + *Rhizobium* culture + PSB	0.132	0.103	0.053
T_{11}	Control	0.130	0.091	0.046
GM		0.134	0.105	0.055

Table 6: Effect of integrated nutrient management on relative growth rate (g g^{-1} day^{-1}) of horsegram

Treatments		Relative growth rate		
		25-50 DAS	50-75 DAS	75 DAS –at harvest
T_1	100% RDF	0.0767	0.0178	0.0065
T_2	125% RDF	0.0785	0.0186	0.0069
T_3	100% RDF + vermicompost(0.5 t ha^{-1})	0.0777	0.0181	0.0067
T_4	100% RDF + Rhizobium culture	0.0780	0.0182	0.0067
T_5	100% RDF + PSB	0.0775	0.0180	0.0066
T_6	100% RDF + Rhizobium culture + PSB	0.0784	0.0183	0.0068
T_7	75% RDF + vermicompost(1 t ha^{-1})	0.0755	0.0173	0.0062
T_8	75% RDF + Rhizobium culture	0.0757	0.0175	0.0064
T_9	75% RDF + PSB	0.0748	0.0171	0.0061
T_{10}	75% RDF + Rhizobium culture + PSB	0.0767	0.0177	0.0064
T_{11}	Control	0.0746	0.0165	0.0060
GM		0.0767	0.0177	0.0065

Number of pod plant^{-1}

The number of pod plant^{-1}was recordedhighest in treatment T_2 (125% RDF) is (30.63), at par with treatment T_6 (100% RDF + *Rhizobium* culture + PSB) is (30.22), Treatment T_4 (100% RDF + *Rhizobium* culture) is (29.86), treatment T_3 (100% RDF + Vermicompost @ 0.5 t ha^{-1}) is (29.41), treatment T_5 (100% RDF + PSB) is (29.21), and T_1 (100%RDF) is (29.10). The lowest number of podplant^{-1} (21.12), is recorded in treatment T_{11} (control), already confirmed by Gupta *et al*. (2017) [4].

Pod length (cm)

Pod length in (cm) was recorded highest in treatment T_2 (125% RDF) is (4.76 cm),at par with treatment T_6 (100% RDF + *Rhizobium* culture + PSB) is (4.65 cm), treatment T_4 (100% RDF + *Rhizobium* culture) is (4.57 cm), treatment T_3 (100% RDF + Vermicompost @ 0.5 t ha-1) is (4.48 cm), treatment T_5 (100% RDF + PSB) is (4.43 cm), and T_1 (100%RDF) is (4.39 cm). The lowest pod length (3.46 cm) is recorded in treatment T_{11} (control).

Number of seed pod^{-1}

Number of seed pod^{-1} is yield attributing factor and the highest number of seed pod^{-1} was recorded in treatment T_2 (125% RDF) is (6.40),at par with treatment T_6 (100% RDF + *Rhizobium* culture + PSB) is (6.38), Treatment T_4 (100% RDF + *Rhizobium* culture) is (6.25), treatment T_3 (100% RDF +Vermicompost @ 0.5 t ha-1) is(6.20), treatment T_5 (100% RDF +PSB) is (6.15), and T_1 (100%RDF) is (5.80). The lowest number of seed pod^{-1} (5.25) is recorded in treatment T_{11} (control).

Test weight (g)

Test weight is weight of 1000 seeds was recorded. The data showed that integrated nutrient management practices had no significant effect on test weight. The highest test weight was observed in treatment T_2 (125% RDF), is (29.97 g) followed by T_6 (100% RDF + *Rhizobium* culture + PSB) is (29.89 g). The lowest number of plant population recorded is (28.92 g) in treatment T_{11} (control). This type of result was already recorded by Khan *et al.*, (2017) [7] on cowpea.

Seed yield (kg ha^{-1})

Seed yield of horsegram was significantly affected with integrated nutrient management practices. Among 11 treatments the highest seed yield was observed intreatment T_2 (125% RDF) is (915.30 kg ha^{-1}), at par with treatment T_6 (100% RDF + *Rhizobium* culture + PSB) is (877.99kg ha^{-1}), treatment T_4 (100% RDF + *Rhizobium* culture) is (846.35 kg ha^{-1}), treatment T_3 (100% RDF + Vermicompost @ 0.5 t ha^{-1}) is (841.13kg ha^{-1}), treatment T_5 (100% RDF +PSB) is (837.83kg ha^{-1}), and T_1 (100% RDF) is (831.03 kg ha^{-1}). The lowest seed yield was (496.30 kg ha^{-1}), is recorded in treatment T_{11} (control).

Straw yield (kg ha^{-1})

Straw yield of horsegram was significantly affected with integrated nutrient management practices. Among 11 treatments the highest straw yield was observed in treatment T_2 (125% RDF) is (1340.00 kg ha^{-1}), at par with treatment T_6 (100% RDF + *Rhizobium* culture + PSB) is (1298.00 kg ha^{-1}), treatment T_4 (100% RDF + *Rhizobium* culture) is (1254.74 kg ha^{-1}), treatment T_3 (100% RDF + Vermicompost @ 0.5 t ha^{-1}) is (1250.99kg ha^{-1}), treatment T_5 (100% RDF +PSB) is (1248.12kg ha^{-1}), and T_1 (100%RDF) is (1243.45 kg ha^{-1}). The lowest seed yield was (800.00kg ha^{-1}), is recorded in treatment T_{11} (control).

Harvest index (%)

The harvest index of horsegram was affected significantly by integrated nutrient management practices. The highest harvest index was observed in treatment T_2 (125% RDF) is (40.58%),at par with treatment T_6 (100% RDF + Rhizobium *culture* + PSB) is (40.34%), treatment T_4 (100% RDF + Rhizobium *culture*) is (40.28%), treatment T_3 (100% RDF +Vermicompost @ 0.5 t ha^{-1})) is (40.20%), treatment T_5 (100% RDF +PSB) is (40.16%), and T_1 (100% RDF) is (40.05%). The lowest harvest index was (38.28%), is recorded in treatment T_{11} (control).

Table 7: Effect of integrated nutrient management on yield attributing characters of horsegram

Treatments		No. of pods	pod length	No. of seeds pod^{-1}	1000 seed weight
T_1	100% RDF	29.10	4.39	5.80	29.68
T_2	125%RDF	30.63	4.76	6.40	29.97
T_3	100%RDF + vermicompost(0.5 t ha^{-1})	29.41	4.48	6.20	29.79
T_4	100%RDF + *Rhizobium* culture	29.86	4.57	6.25	29.85
T_5	100%RDF + PSB	29.21	4.43	6.15	29.73
T_6	100%RDF + *Rhizobium* culture + PSB	30.22	4.65	6.38	29.89
T_7	75%RDF + vermicompost(1 t ha^{-1})	25.90	3.92	5.62	29.01
T_8	75%RDF + *Rhizobium* culture	26.23	3.93	5.65	29.07
T_9	75%RDF + PSB	24.30	3.90	5.60	28.98
T_{10}	75%RDF + *Rhizobium* culture + PSB	26.46	3.95	5.70	29.10
T_{11}	Control	21.12	3.46	5.25	28.92
SEm ±		0.88	0.13	0.11	0.83
CD (P=0.05)		2.60	0.41	0.33	NS

Table 8: Effect of integrated nutrient management on seed yield, straw yield and harvest index of horsegram

Treatments		Seed yield	Straw yield	Harvest index
T_1	100% RDF	831.03	1243.45	40.05
T_2	125%RDF	915.30	1340.00	40.58
T_3	100%RDF + vermicompost (0.5 t ha^{-1})	841.13	1250.99	40.20
T_4	100%RDF + Rhizobium culture	846.35	1254.74	40.28
T_5	100%RDF + PSB	837.83	1248.12	40.16
T_6	100%RDF + Rhizobium culture + PSB	877.99	1298.00	40.34
T_7	75%RDF + vermicompost(1 t ha^{-1})	675.11	1055.00	39.02
T_8	75%RDF + Rhizobium culture	680.00	1060.00	39.08
T_9	75%RDF + PSB	670.00	1050.00	38.95
T_{10}	75%RDF + Rhizobium culture + PSB	690.00	1065.85	39.29
T_{11}	Control	496.30	800.00	38.28
SEm ±		135.50	141.29	-
SEm ±		45.93	47.89	-
CD (P=0.05)		135.50	141.29	

Conclusion

From the result, it was concluded that treatment T_2 (125% RDF) has significantly performed well and achieved the highest in all the parameters.

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