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Morphological response of green gram under different climate resilient crop management practices

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Abstract
Greengram occupied 34.4 lakh ha of area all over India with a production of 14 lakh tonnes and 406.98 kg/ha productivity. India is the largest producer and consumer of pulses in the world accounting for about 35 percent and 25 percent of world's area and production respectively. It occupies a significant place in India for vegetarian people and are considered as rich source of protein. A field experiment was conducted to study climate resilient crop management practices for increasing production and productivity of green gram in rice fallow by application of hydrogel and nano solution at the instructional farm, Odisha University of Agriculture and Technology, Bhubaneswar during rabi 2018-19. The experiment was with sixteen treatments with combination of two cultivar such as Virat and IPM 02- 14 and eight combination of moisture saving elements along with control of environmental and improved practice. All the plants grown in T_8 (Plants grown with Improved practice, Hydrogel, Nano Solution and *Trichoderma*) with Virat variety produces maximum yield and required less water and its water use efficiency was also high. Due to treatment with hydrogel and nano solution the root proliferation occurs and number of root nodules was also increased and it provides maximum yield. As we known root always goes in search of water. So where we applied hydrogel water was available with in a short distance. For this reason the growth of plant is very good here. Height of the plants, number of branches, total number of leaves, number of leaves in main shoot, dry weight of shoot and root leaf, no. and weight of nodules are also high in the plants which are grown under T_8 treatment.

Keywords: Virat, IPM 02- 14, rabi season, hydrogel, nano solution

Introduction
India is the world's largest producer as well as consumer of green gram (*Vigna radiata* L.). Green gram output accounts for about 10-12% of total pulse production in the country. To meet the needs of pulses the traditional rice fallows can be converted into productive lands by growing green gram. While coducting this experiment we adopted different climate resilient crop management practices such as we had developed an artificial drought by minimising the irrigation and to mitigate the dry condition we used hydrogel, nanosolution, *Rhizobium*, *Trichoderma* in greengram so that crop should give optimum yield in the dry condition in rice fallow by utilising the residual soil moisture. Different chemicals like hydrogel and Nano solutions are used to conserve the soil moisture in rabi season. The application of hydrogel in arid and semi–arid regions improve soil properties, increases the water holding capacity of the soil, enhance the soil water retention, improving irrigation efficiency, increase the growth of various crops, and enhancement water productivity of the crop. According to chemical and physical structures of hydrogels, it can be used as absorbent in environment preservation in the agricultural sector as water retention, soil conditioners, and nutrient carriers (Waleed Abobatta., 2018). The hydrogel modified the soil water retention properties. The soil moisture at field capacity increased with the highest hydrogel percentage up to 400% compared to the not amended soil, and at wilting point (-15 bar) was similar to that at field capacity of the not amended soil (Montesano *et al*.,2015) [3]. The effects of hydrogel treatment in sandy loam soil on seed germination or seedling growth of chickpea were not consistent. Seed germination was significantly higher in 0.2% gel treatments compared with control. (Akhter *et al*., 2004) [1]. In loamy and clay soils, AWC is almost doubled (1.8–2.2 fold) at maximum compared to the control. Thus, application of hydrogels can result in significant reduction in the required irrigation frequency (Koupai *et al*., 2008) [2]. "Nano-solutions" is an organic compound which helps plant root enhancement. For rice and legume crops grown in rainfed environments application of "Nano solutions" may increase both subsurface (15-30 cm) soil moisture content and nutrient availability.

Trichoderma harzianum is a safe and effective biocontrol agent in both natural and controlled environments that does not accumulate in the food chain and to which it has not been described resistance (Monte *et al.*, 2003) [3]. So that's why we used such chemicals and biofertilisers in our experiment.

Methodology

The present experiment was laid out at the Agrometeorology research field of College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar during rabi 2018-19. The experimental site is situated at 20º 15' N Latitude and 85º 52' E Longitude at an elevation of 25.9 m above the mean sea level and at about 64 km away from the Bay of Bengal. It comes under the East and South Eastern Coastal Plain Agro climatic Zone of Odisha. The field experiment was conducted in a Factorial Randomized Block Design with three replications. Eight treatments were randomly allotted to the plots as per the lay out plan. Two varieties of green gram such as Virat and IPM 02-14 are used here. The dimension of experimental area was 30 x 35 m^2 with each sub plot dimension. The experimental plots are provided with irrigation channels of 1 meter and the individual plots are demarcated with bunds. Several observations were taken according to the need of research work including pre-harvest, post-harvest and weather data.

Pre harvest observations

Pre-harvest observations include tagged plant data where three tag plants will be selected from each plots and data on height of the plants, number of branches, total number of leaves and number of leaves in main shoot will be observed in 15 days interval. For taking leaf area-data sample plants will be collected and leaf area data will be taken and dry weight of shoot and root leaf, no. and weight of nodules and different growth parameters like Crop growth rate (CGR), Relative growth rate (RGR), Net assimilation rate (NAR) are taken. Phonological observation dates of occurrence of following phonological stages are visually noted, flowering, pod initiation, pod filling, and physiological maturity.

Pre harvest studies

Plant height

Plant height was measured in order to estimate the effect and extent of plant growth due to various treatments. Height of the five selected tagged plants in each plot was measured at 15 DAS and then 15 days interval up to maturity. Height was measured in cm from the soil surface to the main stem (apical).

Root length

Root length was measured in order to estimate the effect and extent of root growth due to various crop management practices. The length of root of five randomly selected plants was recorded in each plot at 15, 30 and 45 DAS. Plants were uprooted carefully and after washing root length recorded.

Branches per plant (no.)

The number of branches per plant was counted from five selected tagged plants in each plot at 15 DAS and subsequently at an interval of 15 days up to maturity.

Leaves per plant (no.)

The numbers of leaves were counted from five selected tagged plants in each plot at 15 DAS and subsequently at an interval of 15 days up to maturity and then averaged out to express in leaves per plant.

Leaf area

All the leaves were removed from the plants for destructive sampling and their leaf area was measured by leaf area meter. Fresh leaves were selected for taking reading. Then they were averaged to get the leaf area per plant.

Leaf area index

Leaf area index (LAI) was calculated by dividing the leaf area per plant by the land area occupied by the plant indicated below

$$LAI = \frac{\text{Total leaf area}}{\text{Ground area}}$$

Total leaf area was found out by multiplying actual leaf area per plant with number of plants m^{-2}.

Shoot dry weight (g)

Shoot dry weight of plant was recorded from randomly selected five plants each plot at 15 DAS and subsequently at an interval of 15 days up to maturity with the help of electronic balance. The collected samples were air dried for a period of two days and then oven dried at 80^0C till the constant weight was obtained.

Root nodules per plant (no.) and fresh weight (mg)

The number of root nodules of five randomly selected plants was recorded in each plot at 15, 30 and 45 DAS. Plants were uprooted carefully and after washing root nodules were separated from the roots, counted, weighted and recorded.

Result and Dissection

Plant height (cm)

Plant height is an important character of the vegetative phase and indirectly influences the yield components. Plant height as a measure of crop growth was recorded at successive stages of crop i.e. 15, 30, 45 DAS and at maturity. The analyzed data is presented in Table 1. The rate of growth in height was higher in the beginning up to 45 DAS, thereafter, it slowed down. The increase in the height was highest between 30 to 45day stage and declined gradually thereafter till harvest. The height of the plant approached at maximum value at maturity. Plant height at all stages was significantly influenced by the treatments. Application of hydrogel with improved practice and seed treatment with nano solution and *Trichoderma* recorded maximum height (38.8cm), which was significantly superior to rest of treatments. The minimum height of the plant was recorded (33.8 cm) in farmers practice (T1) during harvesting.

Number of branches plant

The number of branches recorded at various growth stages from 15 DAS to maturity stage are presented in Table 2. The branches per plant increased till maturity but at slow rate from 45 DAS to maturity. The data revealed that branches developed after 15 DAS and the development was very gradual from 15 – 30 days and from 45 days to maturity whereas the rate of development were relatively much higher from 30 – 45 DAS. The application of hydrogel with improved practice and seed treatment with nano solution and *Trichoderma* recorded maximum number of branches per plant (4.47) at maturity, which was significantly superior to

rest of the treatments except when the greengram was grown with improved practice with application of hydrogel and seed treatment with *Trichoderma*. The minimum number of branches per plant (3.38) was recorded in farmers practice (T1).

Root length

Root length recorded at various growth stages from 15 DAS to maturity stage are presented in Table 3. The root length of plant increased till maturity but at slow rate from 45 DAS to maturity. Root length of plant was affected significantly due to various treatments. Longer roots (14.11 cm) were observed in farmers practice because roots always goes in search of water and here the availability of water is very low. The shortest roots were observed in T8 due to sufficient water availability in root zone.

Number of trifoliate leaves

Leaf number per plant increased rapidly up to 45 DAS and reduced drastically thereafter. Significant difference was observed with regards to number of leaves by different treatments. The highest number of leaves (10.47) was observed hydrogel with improved practice and seed treatment with nano solution and *Trichoderma* (T8) closely followed by plants grown with improved practice and application of hydrogel and seed treatment with nano solution (T7). The minimum number of trifoliate leaves per plant observed in the farmer practice (T7) at 45 DAS.

Leaf area per plant (cm2)

The leaf area of greengram was recorded at fortnight interval starting from 15 DAS till harvest is presented in Table 5. It was evident from data that the leaf area increased progressively with the advancement of crop age. The maximum leaf area per plant was recorded (220.968cm^2) at 45 DAS and subsequently reduced to 110.96
cm^2 at maturity when the crop was grown by application of hydrogel with improved practice and seed treatment with nano solution and *Trichoderma*. Minimum leaf area per plant (82.64 cm^2) is recorded in farmers practice (T1) at harvesting.

Leaf area index

The LAI was estimated at four different growth stages starting from 15 DAS to harvest (Table 6). The data revealed that the LAI increased gradually till 45 DAS and then it declined up to harvest. The highest LAI (0.620 m^2/m^2)was recorded in plants grown with application of hydrogel with improved practice and seed treatment with nano solution and *Trichoderma* (T8), significantly superior to all other treatments.

Shoot dry weight (g plant-1)

Observations regarding shoot dry weight were recorded at four growth stages starting from 15 DAS to harvest at fortnightly interval and presented in the Table 7. Shoot dry weight increased rapidly up to 45 DAS and then the rate of growth became gradual. The highest shoot weight was observed at harvest (10.43 g plant^{-1}) under application of hydrogel with improved practice and seed treatment with nano solution and *Trichoderma* (T8) significantly superior to all other treatments. The lowest shoot weight (7.69 g plant^{-1}) was recorded in farmers practice (T1).

Root nodules plant-1

The number of root nodules per plant was recorded at all stages. The number varies from 15-30 approximately. The trends of data pertaining to number of nodules are given in Table 9. The number of root nodules per plant approached at maximum value on 45 days after sowing. At this stage the maximum number of root nodules (27.3) per plant was observed in plants grown application of hydrogel with improved practice and seed treatment with nano solution and *Trichoderma* (T8). The minimum number of root nodules per plant (3.11) was recorded in plants grown under improved practice with application of hydrogel (T2) at harvesting.

Nodule fresh weight (mg plant -1)

The observations on fresh weight of root nodules were recorded at 15, 30 and 45 DAS. The data presented in Table 10. Relatively heavier nodules (168.50mg plant^{-1}) were observed in plants are grown with application of hydrogel with improved practice and seed treatment with nano solution and *Trichoderma* (T8).which was closely followed by the plants supplemented with hydrogel with improved practice and seed treatment with *Trichoderma* (T7).

Table 1: Plant height (cm) of greengram cultivars at different stages affected by hydrogel, nano solution and *Trichoderma*

Treatments	Plant height (cm)			Harvest
	15 DAS	30 DAS	45 DAS	
T1: Farmers Practice	5.1	16.3	29.4	33.8
T2: IP (Line sowing + FIR + RDF)	5.7	18.8	30.7	34.9
T3: IP+ Hydrogel (@2.5 kg / ha)	4.8	21.2	34.3	36.8
T4: IP+ Nano solution	5.1	18.9	32.5	37.2
T5: IP+ Hydrogel + Nano solution	4.6	18.6	31.8	36.3
T6: IP+ *Trichoderma*	4.9	19.6	32.7	36.7
T7: IP+ Hydrogel + *Trichoderma*	5.4	20.2	33.9	37.6
T8: IP+ Hydrogel+ Nano sol^n+ *Trichoderma*	5.3	20.7	33.8	38.8
S.Em±	0.256	0.762	0.928	0.985
CD (P = 0.05)	0.74	2.20	2.68	2.72
Varieties				
V1: Virat	5.5	18.4	31.4	40.4
V2: IPM 02-14	4.7	20.1	32.1	41.9
S.Em±	0.128	0.464	0.645	0.705
CD (P = 0.05)	0.37	1.34	1.76	2.04
CV %	13.69	13.22	12.46	10.63

Table 2: Number of branches of greengram cultivars at different stages affected by hydrogel, nano solution and *Trichoderma*

Treatments	Number of branches			Harvest
	15 DAS	30 DAS	45 DAS	
T1: Farmers Practice	0.00	1.00	3.47	3.38
T2: IP (Line sowing + FIR + RDF)	0.00	0.93	3.32	3.53
T3: IP+ Hydrogel (@2.5 kg / ha)	0.00	1.00	3.27	3.78
T4: IP+ Nano solution	0.00	0.83	3.40	3.62
T5:IP+ Hydrogel + Nano solution	0.00	1.33	3.93	4.15
T6: IP+ *Trichoderma*	0.00	1.40	4.00	4.18
T7: IP+ Hydrogel + *Trichoderma*	0.00	1.40	4.07	4.26
T8: IP+ Hydrogel + Nano sol^n + *Trichoderma*	0.00	1.42	4.20	4.47
S.Em±	0.00	0.437	0.578	0.63
CD (P = 0.05)	0.00	0.41	0.68	0.72
Varieties				
V1: Virat	0.00	1.31	3.54	3.92
V2: IPM 02-14	0.00	1.30	3.31	3.87
S.Em±	0.00	0.13	0.22	0.17
CD (P = 0.05)	0.00	0.37	0.64	0.48
CV %	0.00	12.63	12.41	13.68

Table 3: Root length (cm) of greengram cultivars at different stages affected by hydrogel, nano solution and *Trichoderma*

Treatments	Root length (cm)			Harvest
	15 DAS	30 DAS	45 DAS	
T1: Farmers Practice	6.10	7.81	14.11	9.72
T2: IP (Line sowing + FIR + RDF)	5.55	7.40	13.15	10.89
T3: IP+ Hydrogel (@2.5 kg / ha)	5.48	7.40	12.31	10.95
T4: IP+ Nano solution	5.41	7.23	11.05	10.92
T5:IP+ Hydrogel + Nano solution	5.26	7.21	10.95	11.74
T6: IP+ *Trichoderma*	5.13	7.18	10.80	12.62
T7: IP+ Hydrogel + *Trichoderma*	5.10	6.91	10.81	13.43
T8: IP+ Hydrogel+ Nano sol^{n}+ *Trichoderma*	5.10	6.85	9.63	14.61
S.Em±	0.437	0.578	1.000	1.021
CD (P = 0.05)	1.26	1.67	2.89	2.93
Varieties				
V1: Virat	6.03	7.39	11.82	11.96
V2: IPM 02-14	4.75	7.11	11.38	11.49
S.Em±	0.115	0.186	0.270	0.290
CD (P = 0.05)	0.33	0.54	0.78	0.81
CV %	11.79	14.16	12.84	12.92

Table 4: Number of trifoliate leaves of greengram cultivars at different stages affected by hydrogel, nano solution and *Trichoderma*

Treatments	No. of trifoliate leaves			Harvest
	15 DAS	30 DAS	45 DAS	
T1: Farmers Practice	1.47	4.13	8.33	3.73
T2: IP (Line sowing + FIR + RDF)	1.53	4.20	8.40	3.99
T3: IP+ Hydrogel (@2.5 kg / ha)	1.60	4.20	8.67	4.07
T4: IP+ Nano solution	1.67	4.87	8.73	4.13
T5: IP+ Hydrogel + Nano solution	1.60	4.93	8.80	4.13
T6: IP+ *Trichoderma*	1.67	5.07	8.87	4.20
T7: IP+ Hydrogel + *Trichoderma*	1.67	5.53	9.73	4.40
T8: IP + Hydrogel + Nano sol^{n}+ *Trichoderma*	1.73	5.93	10.47	4.47
S.Em±	0.09	0.19	0.21	0.18
CD (P = 0.05)	0.23	0.51	0.58	0.53
Varieties				
V1: Virat	1.63	4.89	9.27	4.17
V2: IPM 02-14	1.61	4.65	8.93	4.11
S.Em±	0.06	0.15	0.16	0.14
CD (P = 0.05)	0.18	0.43	0.48	0.41
CV %	12.87	12.21	13.37	12.03

Table 5: Leaf area (cm2) of greengram cultivars at different stages affected by hydrogel, nano solution and *Trichoderma*

Treatments	Leaf area (cm2)			Harvest
	15 DAS	30 DAS	45 DAS	
T1: Farmers Practice	14.7	81.7	131.5	82.6
T2: IP (Line sowing + FIR + RDF)	15.0	144.1	140.8	92.9
T3: IP+ Hydrogel (@2.5 kg / ha)	15.2	97.7	172.6	96.6
T4: IP+ Nano solution	15.3	123.5	135.9	102.1
T5: IP+ Hydrogel + Nano solution	15.7	86.2	143.3	94.1
T6: IP+ *Trichoderma*	14.3	113.3	135.5	101.1
T7: IP+ Hydrogel + *Trichoderma*	14.7	82.7	202.7	107.7
T8:IP+Hydrogel +Nano sol^{n}+ *Trichoderma*	15.7	102.5	220.9	110.9
S.Em±	0.849	5.732	8.432	6.56
CD (P = 0.05)	2.45	16.55	24.35	21.67
Varieties				
V1: Virat	14.8	95.1	167.4	96.4
V2: IPM 02-14	15.1	112.6	152.9	98.2
S.Em±	0.424	2.866	4.216	13.21
CD (P = 0.05)	1.23	8.28	12.17	38.45
CV %	13.62	12.20	14.51	14.64

Table 6: LAI of greengram cultivars at different stages affected by hydrogel, nano solution and *Trichoderma*

Treatments	LAI (m2/m2)			Harvest
	15 DAS	30 DAS	45 DAS	
T1: Farmers Practice	0.043	0.200	0.328	0.275
T2: IP (Line sowing + FIR + RDF)	0.046	0.287	0.447	0.309
T3: IP+ Hydrogel (@2.5 kg / ha)	0.046	0.303	0.461	0.322
T4: IP+ Nano solution	0.046	0.304	0.462	0.340
T5:IP+ Hydrogel + Nano solution	0.046	0.308	0.493	0.313
T6: IP+ *Trichoderma*	0.049	0.308	0.501	0.337
T7: IP+ Hydrogel + *Trichoderma*	0.049	0.308	0.609	0.359
T8: IP +Hydrogel +Nano sol^{n}+*Trichoderma*	0.053	0.361	0.620	0.369
S.Em±	0.002	0.016	0.021	0.019
CD (P = 0.05)	0.01	0.05	0.06	0.05
Varieties				
V1: Virat	0.045	0.300	0.507	0.371
V2: IPM 02-14	0.049	0.294	0.472	0.316
S.Em±	0.001	0.008	0.011	0.007
CD (P = 0.05)	0.00	0.02	0.03	0.02
CV %	14.14	14.69	12.02	13.41

Table 7: Shoot dry weight (g plant-1) of greengram cultivars at different stages affected by hydrogel, nano solution and *Trichoderma*

Treatments	Shoot dry weight (g plant-1)			Harvest
	15 DAS	30 DAS	45 DAS	
T1: Farmers Practice	0.25	2.17	4.63	7.69
T2: IP (Line sowing + FIR + RDF)	0.39	2.78	5.81	8.42
T3: IP+ Hydrogel (@2.5 kg / ha)	0.41	3.27	6.73	8.86
T4: IP+ Nano solution	0.45	3.33	6.87	9.39
T5: IP+ Hydrogel + Nano solution	0.48	3.40	6.93	9.42
T6: IP+ *Trichoderma*	0.46	3.43	7.07	9.51
T7: IP+ Hydrogel + *Trichoderma*	0.46	3.63	7.47	9.73
T8: IP +Hydrogel +Nano sol^{n} +*Trichoderma*	0.54	3.83	8.20	10.43
S.Em±	0.006	0.036	0.042	0.53
CD (P = 0.05)	0.02	0.10	0.13	0.18
Varieties				
V1: Virat	0.46	3.37	6.79	9.17
V2: IPM 02-14	0.42	3.14	6.47	9.06
S.Em±	0.04	0.09	0.17	0.13
CD (P = 0.05)	0.10	0.26	0.50	0.37
CV %	12.56	14.21	12.84	12.05

Table 8: Total dry matter accumulation (g plant-1) of greengram cultivars at different stages affected by hydrogel, nano solution and *Trichoderma*

Treatments	Total dry matter accumulation (g plant^{-1})			Harvest
	15 DAS	30 DAS	45 DAS	
T1: Farmers Practice	0.30	2.38	4.79	7.82
T2: IP (Line sowing + FIR + RDF)	0.45	2.92	5.92	8.67
T3: IP+ Hydrogel (@2.5 kg / ha)	0.48	3.32	6.84	8.92
T4: IP+ Nano solution	0.54	3.40	6.95	9.45
T5: IP+ Hydrogel + Nano solution	0.56	3.42	7.12	9.58
T6: IP+ *Trichoderma*	0.61	3.56	7.37	9.59
T7: IP+ Hydrogel + *Trichoderma*	0.65	3.72	7.58	9.84
T8: IP + Hydrogel + Nano sol^{n} +*Trichoderma*	0.72	3.95	8.34	10.56
S.Em±	0.08	0.14	0.18	0.20
CD (P = 0.05)	0.15	0.27	0.55	0.37
Varieties				
V1:Virat	0.52	3.48	6.86	9.26
V2: IPM 02-14	0.49	3.35	6.57	9.21
S.Em±	0.06	0.11	0.16	0.18
CD (P = 0.05)	0.11	0.23	0.52	0.34
CV %	12.51	14.32	12.46	12.73

Table 9: Number of nodules of greengram cultivars at different stages affected by hydrogel, nano solution and *Trichoderma*

Treatments	Number of nodules			Harvest
	15 DAS	30 DAS	45 DAS	
T1: Farmers Practice	1.2	9.0	17.0	3.34
T2: IP (Line sowing + FIR + RDF)	0.4	5.6	16.6	3.29
T3: IP+ Hydrogel (@2.5 kg / ha)	0.5	11.6	22.8	3.11
T4: IP+ Nano solution	0.4	9.5	15.1	3.31
T5: IP+ Hydrogel + Nano solution	1.4	10.1	18.6	3.40
T6: IP+ *Trichoderma*	1.2	12.3	27.1	3.47
T7: IP+ Hydrogel + *Trichoderma*	1.3	12.0	22.5	3.48
T8: IP + Hydrogel + Nano sol^{n}+*Trichoderma*	1.4	12.8	27.3	3.53
S.Em±	0.21	0.42	0.57	0.19
CD (P = 0.05)	0.59	1.10	1,63	0.58
Varieties				
V1: Virat	0.84	10.2	20.8	3.23
V2: IPM 02-14	0.82	10.5	20.9	3.31
S.Em±	0.19	0.37	0.53	0.15
CD (P = 0.05)	0.56	1.08	1.53	0.44
CV %	12.67	13.75	14.00	12.84

Table 10: Fresh weight of nodules (mg plant-1) of greengram cultivars at different stages affected by hydrogel, nano solution and *Trichoderma*

Treatments	Fresh weight of nodules (mg plant^{-1})			Harvest
	15 DAS	30 DAS	45 DAS	
T1: Farmers Practice	5.8	87.8	158.3	37.8
T2: IP (Line sowing + FIR + RDF)	1.8	86.4	155.2	36.8
T3: IP + Hydrogel (@2.5 kg / ha)	3.3	86.5	153.7	36.6
T4: IP + Nano solution	1.9	87.4	158.4	52.4
T5: IP + Hydrogel + Nano solution	7.3	97.3	162.2	49.1
T6: IP + *Trichoderma*	8.2	97.9	164.5	52.4
T7: IP + Hydrogel + *Trichoderma*	7.8	98.4	163.4	49.9
T8: IP + Hydrogel + Nano sol^{n} + *Trichoderma*	8.6	107.2	168.5	56.6
S.Em±	0.58	3.49	3.16	1.98
CD (P = 0.05)	1.56	9.96	9.15	5.87
Varieties				
V1: Virat	7.8	92.1	158.7	42.6
V2: IPM 02-14	7.5	91.8	157.7	43.5
S.Em±	0.53	3.46	3.09	1.94
CD (P = 0.05)	1.53	9.93	9.01	5.73
CV %	13.87	12.89	13.06	12.75

Conclusion

The study revealed that application of hydrogel with improved practice and seed treatment with nano solution and *Trichoderma* (T8) produced the significantly higher yield (752.2 kg ha^{-1}). Higher yield in this treatment is due to higher root proliferation (14.11 cm), higher number nodules (27.3), higher fresh weight of nodules (168.5 mg plant^{-1}), higher leaf number (10.47) as compared to all other treatments. Among two varieties Virat gives better results than IPM 02-14. It matured within 55-58 days, so it is a better choice for rice fallow than the other one. The combination of T8 with variety Virat gives best result.

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