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Impact of added Phosphorus and Phosphorus Solubilizing Bacteria in Yield and Yield Attributes of Mungbean *(Vigna Radiata L.)*

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Abstract— *Mungbean is an excellent rotational legume crop for farmers with small land holdings. Phosphorus Solubilizing Bacteria (PSB) solubilizes phosphorus to make it available to the plant so, their integration can be a supporting factor to increase its yield and enhance soil fertility. A field experiment was conducted at the Agronomy Research Farm of the Institute of Agriculture and Animal Sciences (IAAS), Paklihawa Campus, Rupandehi during the summer season of 2023. The experiment comprised seven treatments, namely T1: Control, T2: 10 kg P2O5ha-1 , T3: 15 kg P2O5ha-1 , T4: 20 kg P2O5ha-1 , T5: 10 kg P2O5ha-1 + PSB, T6: 15 kg P2O5ha-1 + PSB, T7: 20 kg P2O5ha-1 + PSB tested in Randomized Block Design and replicated three times. Pratigya variety of Mungbean was used. The soil of the experimental field was medium in organic matter, nitrogen, phosphorus, and potassium before the experiment. The analysis was done in R studio software. Results revealed that all the growth and yield attributes increased significantly ($p < .05$) under the integrated treatment (20 kg P2O5ha-1 + PSB). The growth characters viz., plant height (61.65 ± 1.25 cm), nodule number (23.90 ± 2.22), dry matter accumulation(30.74± 1.37 g), and yield attributes like the number of pod plant-1 (26.6± 1.00), pod length (8.24 cm ± 0.05), the number of grains pod-1 (8.84 ± 0.08), biological yield (30.2 ± 0.79 mt/ha), seed yield (2.44 ± 0.05 mt/ha) and harvest index (7.51 ± 0.18 %) increased significantly in T7 (20 kg P2O5 ha-1 PSB).*

Keywords— ***Mungbean, Phosphorus, Phosphorus Solubilizing Bacteria (PSB), Nodules, Yield***

I. INTRODUCTION

Mung bean (Vigna radiata), popularly known as green gram belongs to the family Fabaceae and has been consumed as a common traditional food for more than 3500 years across the world. Kole, C. (2007). Mung bean is an excellent rotation crop for smallholder farmers because of its short crop duration, tolerance to heat, minimal input requirement, and strong global demand. It provides its users with a triple benefit: more money, more nutrient-rich food, and more fertile soil (Nair et al., 2020). The crop responds favorably to the application of fertilizer phosphorus. It is the second most crucial macronutrient needed by plants after nitrogen. The characteristics of phosphorus nutrition include root development, stalk, and stem strength, flower and seed formation, crop maturity and production, N-fixation in legumes, crop quality, and resistance to plant diseases. Although microbial inoculants have been used to increase soil fertility over the past century, P solubilization research has been reported on much less frequently than nitrogen fixation (Jilani et al., n.d.) By providing assimilates to the roots, phosphorus not only plays a crucial function in root growth and proliferation but also enhances nodulation and N fixation (Kumar & Yadav, 2018). By increasing the soil microbial biomass and reducing the ineffective nodules, phosphate-solubilizing bacteria (PSB) like *Pseudomonas striata* and *Bacillus polymyxa* showed that mung bean growth and productivity had been positive, offering a biotechnological solution for sustainable agriculture(Hassan et al., 2017). PSB inoculation increases

the concentration of phosphorus in shoots and roots and its uptake in Mungbean varieties.

II. MATERIALS AND METHODS

A research entitled "Impact of added phosphorus and Phosphorus Solubilizing Bacteria (PSB) in yield and yield attributing characters of Mungbean (*Vigna radiata L.*)" was conducted at the agronomy farm of IAAS (Institute of Agriculture and Animal Science), Paklihawa campus during the summer season in 2023. The latitude and longitude of the farm's location are 27° 28' 48.252" North and 83° 26' 50.172"East respectively and 108 meters above sea level. The soil of the site before the research was 8.58. The climate of Paklihawa where the experiment was conducted is sub-tropical humid with very little rainfall. The size of the experimental unit was 4 m² (2 m*2m). The experiment was laid out in a Simple Randomized Complete Block Design (RCBD) with 7 treatments and 3 replications. Mungbean variety, Pratigya with different doses of phosphorus fertilizer, and PSB inoculation were the treatments. The collected data were tabulated in an MS Excel worksheet and analyzed in R studio software.

III. RESULTS AND DISCUSSION

3.1 Growth attributes

3.1.1 Plant height

Plant heights were recorded at 20DAS, 40DAS, 60DAS, and during harvest. At all growth stages plant height was maximum in T_7 (i.e. 13.47cm at 20DAS, 32.26cm at 40DAS, 55.06cm at 60DAS, and 61.65cm during harvest).

PSB inoculation with phosphorus fertilizer improved the availability of soluble phosphorus, which aided in plant growth and resulted in higher plant height (Singh et al., 2021).

3.1.2 Nodulation

Nodule numbers were recorded at 20DAS, 40DAS and 60DAS. The nodule number was significantly higher at T7 during all growth stages (i.e. 7.43 at 20DAS, 15.00 at 40DAS, and 29.90 at 60DAS). A higher No. of nodules/plant at a higher P level may have given better growth, which helps for nodule formation as PSB solubilizes insoluble P making it available to the plants. This is similar to the results of (Sumanth & Singh, 2021).

3.1.3 Dry matter

The finding of our research about dry matter content was not significant at 20DAS but significantly increased at 40DAS, 60DAS, and during harvest. The highest dry matter was observed in 20 kg P2O5/ha + PSB at all growth stages i.e. 0.247gm at 20DAS, 4.39gm at 40DAS, 26.14gm at 60DAS, and 30.74gm during harvest.

The increased availability of N, and P and their synergistic effect might have caused better dry matter accumulation, and as a result increase in the value of the above growth parameters was observed. Similar observation was also found in Mitra et al., (1999); and Perveen et al., (2002).

3.2 Yield and Yield Attributes

3.2.1 Pods per plant

Pods per plant were recorded highest in T7 i.e. 26.60 pods. The favorable role of phosphorus is mainly due to its primary effect in photosynthesis by way of rapid energy transfer which affects various biochemical processes from the beginning of seedling growth to the formation of grain and maturity (Sumanth & Singh, 2021).

3.2.2 Pod length

Pod length increased with phosphorus and PSB application in T7 which was recorded to be 8.24 cm. This might be due to the increase in vegetative development and reproductive attributes under proper availability of phosphorus and better physical condition of soil. The same results were revealed by Choudary et al., (2014).

3.2.3 Grains per pod

The highest grains per pod was recorded in T7 with 8.84 grains per pod. This is due to an increase in photosynthetic activity of leaves and translocation of photosynthates from source to sink and nutrient uptake by the application of bio-fertilizer and phosphorus dose. The minimum values of all the attributes were observed under the control plot because plants were unable to receive more nutrients. The results agree with those of Prakash et al. (2002).

3.2.4 Thousand seed weight

An increase in thousand seed weight was insignificant in T7 with the value 38.89 g. The increased availability of N, and P and their synergistic effect might have caused better dry matter accumulation, and as a result increase in the value of the above growth parameters was observed. Similar observation was also made by Mitra et al., (1999); Perveen et al., (2002).

3.2.5 Grain yield

The highest grain yield was obtained in T7 i.e. 2.44 ton/ha. Phosphorus is also a component of RNA, the compound that reads the DNA genetic code to build proteins and other compounds essential for plant structure, seed yield, and genetic transfer. These results are in line with Chowdary et al., (2003); and Yadav (2004).

3.2.6 Biological yield

Higher stover yield in the highest phosphorus treatment and PSB (30.2t/ha), though insignificant difference, might be due to increased availability of P which favored nodule formation, higher nitrogen fixation, dry matter accumulation, rapid growth, higher absorption, and utilization of other nutrients. The same results were revealed by Choudary et al., (2014).

3.2.7 Harvest Index (HI)

An increase in harvest index with phosphorus application (7.51 in T7) is the indication of better translocation of photosynthates from source to sink. These results confirm with the findings of (Singh et al., 2018).

IV. SUMMARY AND CONCLUSION

Results suggest that Mung bean can be an excellent rotational crop as it improves soil fertility as verified by various soil test results. The PSB helps to make insoluble phosphorus available to the plant by converting it into a soluble form. The plant, then, uses phosphorus for root growth, nodule development, and pod development. Ultimately, this results in better soil health and crop performance. As seen in the research, Phosphorus, Nitrogen, Potassium, and Organic Matter increased significantly in the integrated treatment of the highest level of phosphorus and PSB. Integrating phosphorus with PSB significantly increases growth, nodule number, yield, and yield-attributing characters in Mungbean.

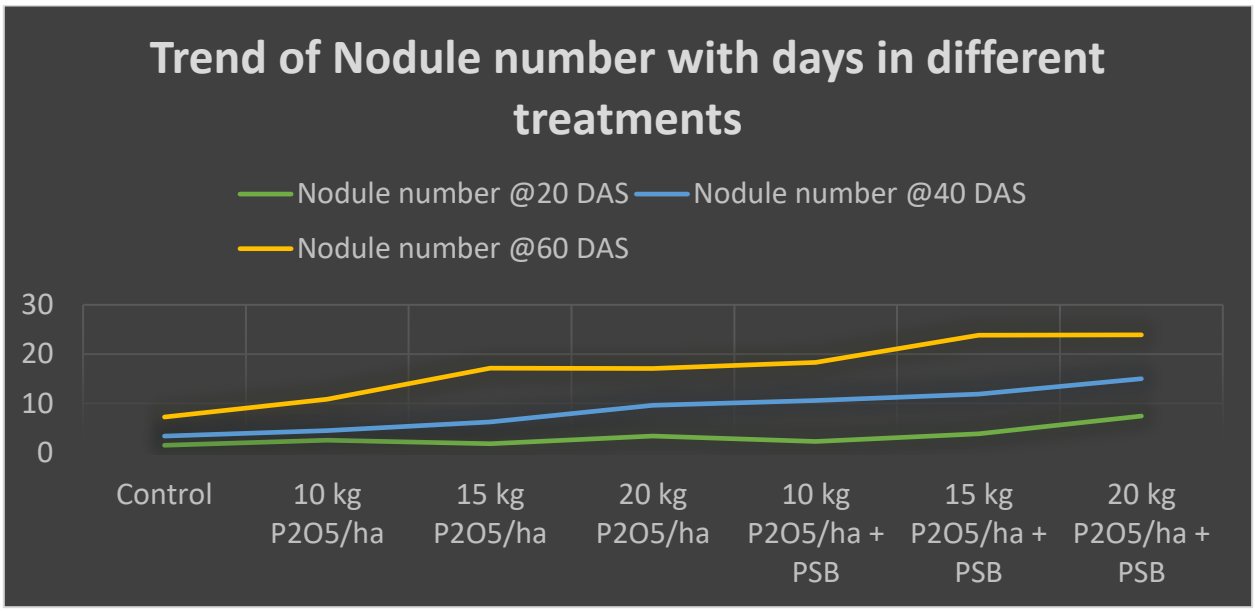

Fig.1: Effect of Phosphorus levels and PSB on nodule number at 20, 40 and 60 days of sowing

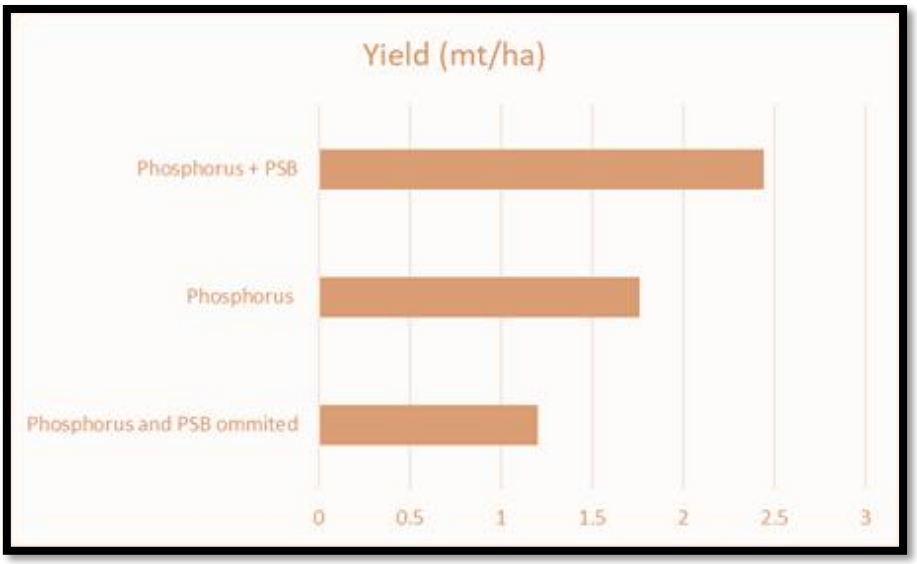

Fig.2: Yield variation in different conditions of fertilizer and bacteria addition in Mungbean at Paklihawa, 2023

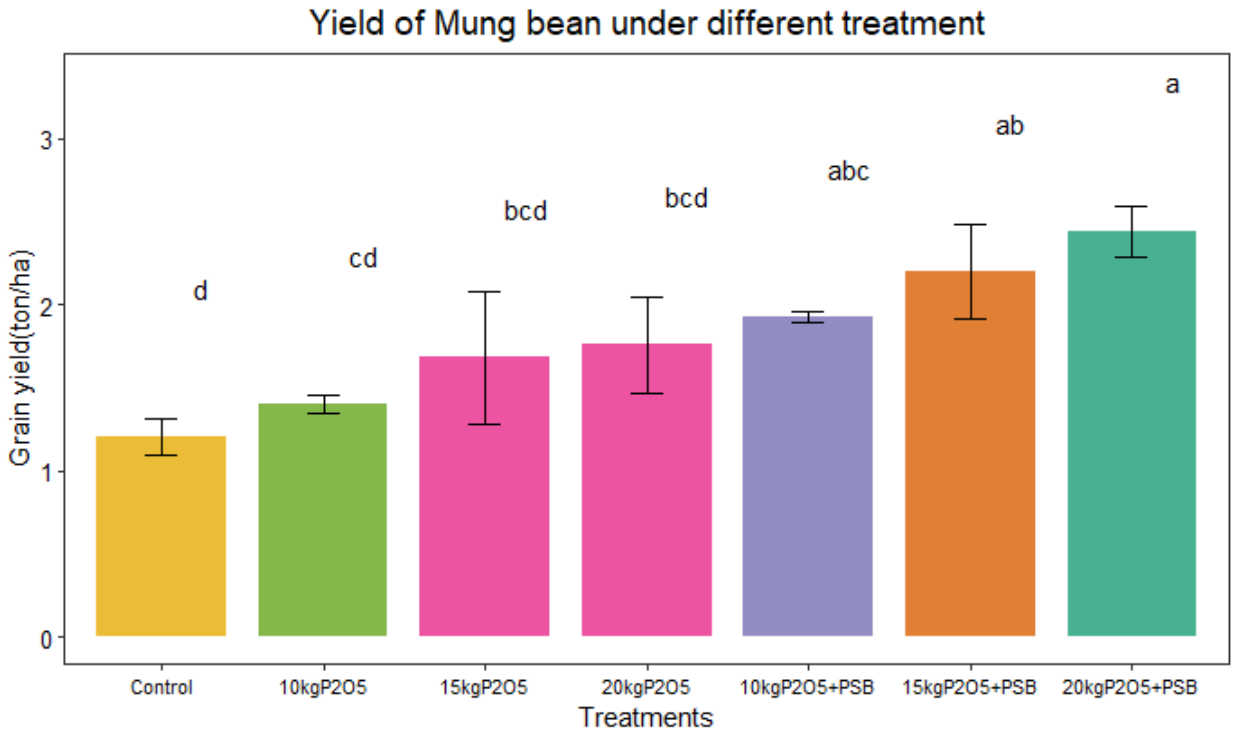

Fig.3: Effect of Phosphorus levels and PSB on yield of Mungbean at Paklihawa, 2023

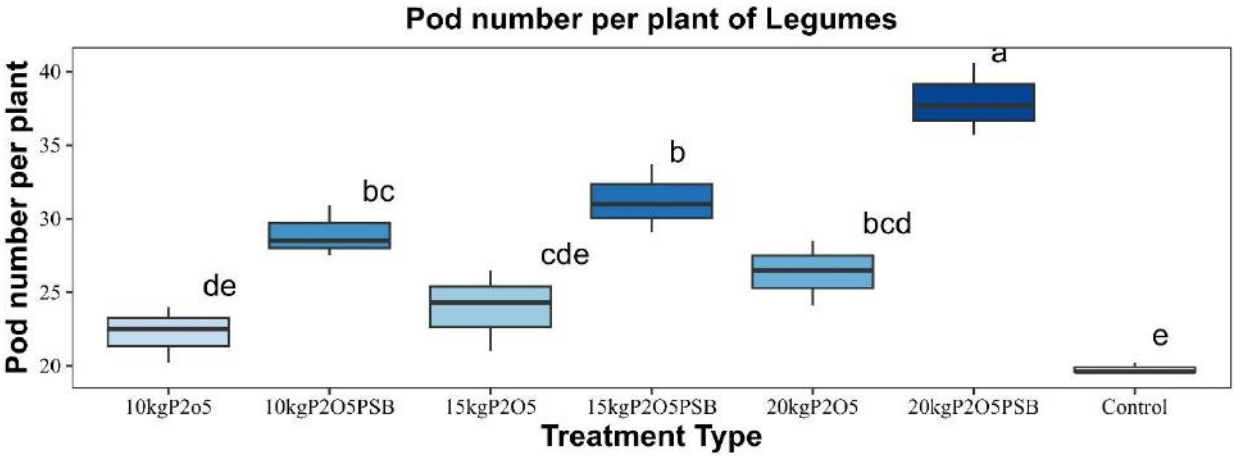

Fig.4: Effect on pod number per plant in different treatments of phosphorus and PSB in Mungbean at Paklihawa, 2023

Table -1 Effect of added phosphorus and PSB on plant height of Mungbean at Paklihawa, 2023

Treatments	Plant height@ 20DAS	Plant height@40DAS	Plant height@60DAS	Plant height during harvest
T1	11.63 ± 0.22^{c}	26.02 ± 0.46^{c}	47.21 ± 0.58^{e}	52.19 ± 0.92^{d}
T2	11.86 ± 0.44^{bc}	27.37 ± 0.56^{bc}	49.11 ± 0.60^{d}	54.66 ± 0.21^{cd}
T3	12.53 ± 0.54^{abc}	27.73 ± 0.71^{bc}	51.01 ± 0.67^{c}	55.54 ± 0.40^{cd}
T4	12.81 ± 0.07^{abc}	28.57 ± 0.48^{bc}	51.57 ± 0.64^{c}	56.79 ± 0.22^{bc}
T5	13.23 ± 0.14^{ab}	29.87 ± 0.81^{ab}	52.61 ± 0.60^{bc}	57.71 ± 1.04^{bc}
T6	12.82 ± 0.40^{abc}	30.39 ± 0.63^{ab}	53.45 ± 0.46^{ab}	60.51 ± 0.96^{ab}

T7	13.47±0.46[a]	32.26±0.63[a]	55.06±0.49[a]	61.65±0.68[a]
LSD	1.41	3.04	1.69	3.57
F-Prob	ns	*	***	**
SEm (±)	0.25	0.79	1.0007	1.245
CV (%)	6.28	5.93	1.85	3.52
Grand mean	12.62	28.88	51.43	57.009

Table -2 Effect of added phosphorus and PSB on nodule number of Mungbean at Paklihawa,2023

Treatments	Nodule number @20DAS	Nodule number @40DAS	Nodule number @60DAS
T1	1.5±0.64[b]	3.37±0.12[d]	7.23±0.24[c]
T2	2.5±0.45[b]	4.50±0.48[d]	10.83±1.43[bc]
T3	1.83±0.78[b]	6.23±0.32[cd]	17.17±2.87[ab]
T4	3.37±0.65[b]	9.63±1.91[bc]	17.10±2.74[ab]
T5	2.27±0.58[b]	10.60±0.65[b]	18.30±2.57[a]
T6	3.83±0.15[b]	11.90±0.20[ab]	23.80±3.51[a]
T7	7.43±0.37[a]	15.00±0.56[a]	23.90±3.38[a]
LSD	2.29	3.82	6.49
F-Prob	**	***	***
SEm (±)	0.76	1.59	2.33
CV (%)	39.69	24.52	21.59
Grand mean	3.24	8.75	16.904

Table -3 Effect of added phosphorus and PSB on dry matter of Mungbean at Paklihawa, 2023

Treatments	Dry matter@ 20 DAS	Dry matter@40 DAS	Dry matter@60 DAS	Dry matter during harvest
T1	0.16±0.01[b]	1.99±0.17[d]	12.65±1.15[c]	19.35±0.36[e]
T2	0.21±0.02[ab]	3.18±0.27[bc]	15.74±1.74[bc]	22.68±1.36[d]
T3	0.19±0.02[ab]	2.63±0.09[cd]	16.44±0.63[bc]	24.37±2.33[cd]
T4	0.21±0.01[ab]	3.26±0.17[bc]	19.11±1.70[b]	26.06±2.50[bc]
T5	0.22±0.24[ab]	3.73±0.32[ab]	17.33±1.1[bc]	25.96±0.28[bc]
T6	0.23±0.01[a]	3.54±0.23[abc]	19.32±3.60[b]	27.59±2.13[b]
T7	0.25±0.01[a]	4.39±0.52[a]	26.14±0.89[a]	30.74±2.51[a]
LSD	0.06	0.89	4.96	1.92
F-Prob	ns	**	**	***
SEm (±)	0.01	0.29	1.58	1.37
CV (%)	15.68	15.40	15.41	4.28

Grand mean	0.21	3.25	18.10	25.25

Table-4 Effect of added phosphorus and PSB on yield and yield attributing characters of Mungbean at Paklihawa, 2023

Treatments	Pod per plant	Pod length (cm)	Grains per pod	Test Weight (g)	Grain yield (mt/ha)	Biological yield (mt/ha)	Harvest Index (%)
T_1	19.37 ± 0.12^{g}	6.96 ± 0.06^{e}	6.95 ± 0.09^{d}	35.64 ± 1.11^{a}	1.20 ± 0.041^{e}	17.8 ± 0.3^{e}	6.30 ± 0.14^{a}
T_2	20.93 ± 0.51^{f}	6.44 ± 0.11^{d}	7.21 ± 0.04^{d}	36.30 ± 0.86^{a}	1.40 ± 0.019^{de}	21.1 ± 1.11^{de}	6.27 ± 0.23^{a}
T_3	23.63 ± 0.43^{e}	7.55 ± 0.11^{cd}	7.58 ± 0.01^{c}	36.85 ± 2.79^{a}	1.68 ± 0.14^{cd}	22.8 ± 0.72^{cd}	6.94 ± 0.75^{a}
T_4	24.47 ± 0.37^{d}	7.69 ± 0.11^{bcd}	7.87 ± 0.08^{c}	37.19 ± 1.52^{a}	1.76 ± 0.10^{cd}	24.8 ± 1.18^{cd}	6.74 ± 0.65^{a}
T_5	25.20 ± 0.18^{c}	7.82 ± 0.07^{bc}	8.31 ± 0.09^{b}	37.35 ± 0.16^{a}	1.93 ± 0.012^{bc}	26.8 ± 0.88^{bc}	6.75 ± 0.20^{a}
T_6	25.83 ± 0.30^{b}	7.95 ± 0.05^{b}	8.77 ± 0.08^{a}	38.24 ± 1.86^{a}	2.20 ± 0.10^{ab}	27.8 ± 1.06^{ab}	7.39 ± 0.51^{a}
T_7	26.60 ± 0.17^{a}	8.24 ± 0.05^{a}	8.84 ± 0.08^{a}	38.89 ± 0.86^{a}	2.44 ± 0.05^{a}	30.2 ± 0.79^{a}	7.51 ± 0.23^{a}
LSD	0.47	0.27	0.35	7.76	0.40	4.73	1.83
F-Prob.	***	***	***	ns	***	***	Ns
SEm	1.00	0.15	0.28	0.42	0.16	2.00	0.18
CV (%)	1.11	1.99	2.48	11.72	12.57	10.53	15.10
Grand mean	23.72	7.67	7.93	37.20	1.80	25.27	6.84

Table-5 Effect of added phosphorus and PSB on soil parameters before cultivation and after harvest of Mungbean at Paklihawa, 2023

Soil parameters	Total Nitrogen (%)	Phosphorus (kg/ha)	Organic matter (%)
Before Mungbean cultivation	0.04	35.88	1.77
T1	0.06^{b}	34.27^{e}	1.83^{e}
T2	0.074^{ab}	37.61^{d}	1.90^{d}
T3	0.076^{ab}	44.17^{c}	2.17^{c}
T4	0.09^{ab}	47.17^{b}	2.20^{c}
T5	0.08^{ab}	47.45^{b}	2.37^{bc}
T6	0.09^{ab}	48.17^{b}	2.79^{ab}
T7	0.1^{a}	54.7^{a}	3.32^{a}
LSD	0.026	2.85	0.95

F-Prob.	ns	***	***
SEm	0.0049	2.6	0.54
CV (%)	14.2	3.58	11.41
Grand mean	0.08	44.79	2.28

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