

## **Influence of phosphatesolubilizing microorganisms and phosphorus levels on growth yield and quality of chickpea (*Cicer arietinum* L.) in inceptisol.**

**Comment [sd1]:** Influence can be replaced by Effect

### **Abstract**

A field study was conducted to know the “Influence of phosphatesolubilizing microorganisms and phosphorus levels on growth, yield and quality of chickpea (*Cicer arietinum* L.) in inceptisol.” The experiment was laid in factorial randomized block design (FRBD) with sixteen treatments, replicated thrice during Rabi 2019-20 at department research farm of SSAC, College of Agriculture, Latur. The treatments comprises four main (absolute control, *Bacillus megaterium*, *Aspergillus niger* and *Aspergillus awamori* @ 10 ml kg<sup>-1</sup> seed treatment) and four sub treatments (0, 45, 60 and 75 P<sub>2</sub>O<sub>5</sub> kg ha<sup>-1</sup>). The results indicates that, the incorporation of phosphatesolubilizing microorganisms viz. *Aspergillus awamori* @ 10 ml kg<sup>-1</sup> seed in combination with soil application of 75 P<sub>2</sub>O<sub>5</sub> kg ha<sup>-1</sup> found to be effective in improving growth and yield attributing characters viz. number of root nodules, fresh and dry weight, chlorophyll content, grain yield and straw yield as compared to *Aspergillus niger* and *Bacillus megaterium* along with 60 P<sub>2</sub>O<sub>5</sub> kg ha<sup>-1</sup> and over control. Further results revealed that test weight and protein percentage was significantly influenced with the seed treatment of *Aspergillus awamori* @ 10 ml kg<sup>-1</sup> seed in combination with application of 75 P<sub>2</sub>O<sub>5</sub> kg ha<sup>-1</sup>.

**Keywords:** chickpea, microorganisms, phosphorus, quality, yield

### **Introduction**

Chickpea is the Rabi pulse crop grown in country supplementing protein (17-25 per cent), amino acid, Vit. A, Vit. C, Vit. B, Vit. K, source of folic acid for demand of vegetarian diet, also it plays a significant role in improving soil fertility by fixing the atmospheric nitrogen. Phosphorus can be termed as ‘life mineral’ because of its crucial role in metabolic and energy transfer reactions in plant. Phosphorus is an essential element in DNA and RNA that contain the genetic code of the plant to produce protein and other compounds essential for plant structure, seed yield and also associated with increased root growth, chlorophyll content, and N<sub>2</sub>-fixation in legumes. Use of phosphorous in soils phosphorous solubilizing microorganisms (PSMs) and unlike bacteria, soil fungi also have ability to are capable

to convert insoluble phosphorous to soluble forms can function as biofertilizers to increase the native phosphorous in soil (Narsian andpatel, 2000)<sup>[07]</sup>. It is low cost renewable source of plant nutrients, which supplement chemical fertilizer. Mittal *et al.*,(2008) <sup>[06]</sup>found that seed inoculation of chickpea with *Aspergillus awamori* increased shoot height by 7-12 per cent, a nearly 3 fold increase in seed weight as compared to un inoculated control. Seed inoculation with *Aspergillus awamori* increased the growth, total P content and biomass of mungbean (Jain *et al.*, 2012)<sup>[02]</sup>.

**Comment [sd2]:** Insufficient References

### Material and Methods

The field experiment was conducted during *Rabi* 2019-20 at research farm departmental farm of SSAC, College of Agriculture, Latur using chickpea crop (Var.BDNG-797).

In order to evaluate the interactive effect of phosphates solubilizing microorganisms and phosphorus levels on growth parameter, grain yield and seed quality of chickpea. After completion of preparatory tillage operations, the experiment was laid out in factorial randomized block design (FRBD) with sixteen treatments replicated thrice.

Organic manures i.e. FYM was applied at the rate of 5 t ha<sup>-1</sup> prior to 15 days of sowing of chickpea crop and all the plots were fertilized with recommended dose of fertilizer NPK (25:50:00 kg ha<sup>-1</sup>) was applied as a basal dose through urea, SSP treatment wise at the time of sowing. The treatments comprises as a seed treatment T<sub>0</sub>: Control, T<sub>1</sub>: *Bacillus megaterium* @ 10 ml kg<sup>-1</sup> seed, T<sub>2</sub>: *Aspergillus niger* @ 10 ml kg<sup>-1</sup> seed, T<sub>3</sub>: *Aspergillus awamori* @ 10 ml kg<sup>-1</sup> seed as a main treatments and application P<sub>0</sub>: 0 P kg ha<sup>-1</sup>, P<sub>1</sub>: 45P kg ha<sup>-1</sup>, P<sub>2</sub>: 60P kg ha<sup>-1</sup>, P<sub>3</sub>: 75P kg ha<sup>-1</sup> as a sub main treatments.

**Comment [sd3]:** Potassium dose is really 00 Kg/ha.

Chickpea seed was sown on 09<sup>th</sup> October 2019 by dibbling method as per randomly replicated plot having size 3 × 2 m<sup>2</sup> maintained row to row spacing 30 cm and plant to plant 10 cm and using a seed rate of 80 kg ha<sup>-1</sup>. After sowing, seed was covered with soil. Sowing depth was kept almost 5 cm. The crop was harvested at maturity stage on 22 January 2020. The observation recorded viz. number of the nodules per plant was recorded at 45 and 60 DAS. The fresh weight and dry weight was also weighed in grams. The seed yield, fodder yield were recorded at harvest stage. Quality parameter like protein, and test weight value were recorded. The data collected from the above observation were analysed statistically by the procedure prescribed by Panse and Sukhatme (1967)<sup>[09]</sup>.

**Comment [sd4]:** Maintain the format

## Result and Discussion

### Total number of root nodule:

Total number of root nodule per plant expressed in table 1. It was observed that, among the different treatments, Total number of root nodule per plant of chickpea were recorded significantly maximum (15.83 and 18.50 per plant) with seed inoculation of *Aspergillus awamori*, followed by declined up to 13.33 to 16.00 with *Aspergillus niger* and 13.16 and 14.75 with *Bacillus megaterium* at 45 and 60 DAS, respectively. Whereas, the number of nodules per plant was recorded minimum in control at 45 and 60 DAS (i.e. 10.83 and 13.33 respectively). The data showed that maximum root nodules of chickpea (15.67 and 18.41) per plant was recorded with application @ 75 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> increased at 45 and 60 DAS respectively. The number of root nodules per plant was further decreased to minimum (11.58 and 14.16) in control at 45 and 60 DAS of chickpea respectively.

Table No. 1: **Nodules per plant of chickpea as influenced by phosphatesolubilizing microorganisms and phosphorus levels.**

PSM	Phosphorus levels (P <sub>2</sub> O <sub>5</sub> kg ha <sup>-1</sup> )				
	P0	P45	P60	P75	Mean
	<b>Number of nodules per plant at 45 DAS</b>				
<b>T0</b>	10.00	10.33	10.33	12.67	<b>10.83</b>
<b>T1</b>	11.67	13.00	13.33	14.67	<b>13.16</b>
<b>T2</b>	11.67	12.67	13.00	16.00	<b>13.33</b>
<b>T3</b>	13.00	15.00	16.00	19.33	<b>15.83</b>
<b>Mean</b>	<b>11.58</b>	<b>12.75</b>	<b>13.17</b>	<b>15.67</b>	
	<b>T</b>		<b>P</b>		<b>TXP</b>
<b>SE</b>	<b>0.20</b>		<b>0.20</b>		<b>0.40</b>
<b>C.D at 5%</b>	<b>0.57</b>		<b>0.57</b>		<b>1.15</b>
	<b>Number of nodules per plant at 60 DAS</b>				
<b>T0</b>	11.66	12.66	13.33	15.66	<b>13.33</b>
<b>T1</b>	13.33	14.00	14.66	17.00	<b>14.75</b>
<b>T2</b>	14.33	15.66	15.00	19.00	<b>16.00</b>
<b>T3</b>	17.33	15.66	19.00	22.00	<b>18.50</b>
<b>Mean</b>	<b>14.16</b>	<b>14.50</b>	<b>15.50</b>	<b>18.41</b>	
	<b>T</b>		<b>P</b>		<b>TXP</b>
<b>SE</b>	<b>0.22</b>		<b>0.22</b>		<b>0.45</b>
<b>C.D at 5%</b>	<b>0.65</b>		<b>0.65</b>		<b>1.31</b>

The interaction effect of phosphatesolubilizing microorganisms and phosphorus levels was found significant at 45 and 60 DAS. The increase in the root nodules per plant of chickpea due to seed inoculation of *Aspergillus awamori* increase

d the availability of soluble phosphorus by production of organic acid, this acid solubilize unavailable phosphate to available phosphorus helps to enhance nitrogen fixation which leads to increase in the number of root nodules per plant of chickpea. Similarly, phosphorus plays an important role in nodule initiation and increase the root proliferation thereby increase in the root nodules (Paratey and Wani, 2005)<sup>[10]</sup>. Similar results also reported by Vidhyashree *et al.*, (2017)<sup>[14]</sup>.

**Fresh and Dry weight of root nodules:**

Data in respect of fresh and dry weight of root nodules of chickpea presented in the table 2. Among the phosphates solubilizing microorganisms seed inoculation of *Aspergillus awamori* recorded significant fresh and dry weight of root at 45 DAS (0.23 and 0.13 g) and at 60 DAS (0.54 and 0.33 g). While minimum fresh and dry weight of nodule was recorded in control (0.12 and 0.05 g). The similar pattern was observed in fresh and dry weight at 60 DAS.

**Table 2: Fresh and dry weight of root nodule in chickpea as influenced by phosphates solubilizing microorganisms and phosphorus levels.**

PSM	Phosphorus levels ( $P_2O_5$ kg ha <sup>-1</sup> )				
	P0	P45	P60	P75	Mean
	Fresh Weight of Root Nodules at 45 DAS (g)				
T0	0.10	0.12	0.13	0.14	<b>0.12</b>
T1	0.14	0.16	0.18	0.19	<b>0.17</b>
T2	0.20	0.20	0.21	0.22	<b>0.21</b>
T3	0.22	0.23	0.21	0.26	<b>0.23</b>
Mean	<b>0.16</b>	<b>0.18</b>	<b>0.18</b>	<b>0.20</b>	
	T		P		TXP
SE	<b>0.002</b>		<b>0.002</b>		<b>0.005</b>
C.D at 5%	<b>0.008</b>		<b>0.008</b>		NS
Dry Weight of Root Nodules at 45 DAS (g)					
T0	0.02	0.03	0.04	0.10	<b>0.05</b>
T1	0.06	0.08	0.09	0.10	<b>0.08</b>
T2	0.10	0.11	0.12	0.11	<b>0.11</b>
T3	0.13	0.15	0.12	0.11	<b>0.13</b>
Mean	<b>0.07</b>	<b>0.09</b>	<b>0.09</b>	<b>0.11</b>	
	T		P		TXP
SE	<b>0.003</b>		<b>0.003</b>		<b>0.008</b>
C.D at 5%	<b>0.010</b>		<b>0.010</b>		NS

Fresh Weight of Root Nodules at 60 DAS (g)					
--	--	--	--	--	--

<b>T0</b>	0.17	0.18	0.19	0.20	<b>0.18</b>
<b>T1</b>	0.26	0.27	0.29	0.32	<b>0.28</b>
<b>T2</b>	0.33	0.33	0.38	0.40	<b>0.36</b>
<b>T3</b>	0.47	0.52	0.56	0.62	<b>0.54</b>
<b>Mean</b>	<b>0.31</b>	<b>0.32</b>	<b>0.35</b>	<b>0.38</b>	
	<b>T</b>		<b>P</b>		<b>TXP</b>
<b>SE</b>	<b>0.008</b>		<b>0.008</b>		<b>0.015</b>
<b>C.D at5%</b>	<b>0.017</b>		<b>0.017</b>		<b>0.04</b>
<b>Dry Weight of Root Nodules at 60 DAS (g)</b>					
<b>T0</b>	0.06	0.08	0.12	0.11	<b>0.09</b>
<b>T1</b>	0.17	0.15	0.16	0.14	<b>0.15</b>
<b>T2</b>	0.17	0.17	0.20	0.22	<b>0.19</b>
<b>T3</b>	0.26	0.30	0.35	0.42	<b>0.33</b>
<b>Mean</b>	<b>0.16</b>	<b>0.17</b>	<b>0.20</b>	<b>0.22</b>	<b>NS</b>
	<b>T</b>		<b>P</b>		<b>TXP</b>
<b>SE</b>	<b>0.012</b>		<b>0.012</b>		<b>0.024</b>
<b>C.D at5%</b>	<b>0.035</b>		<b>0.035</b>		<b>NS</b>

Among the different levels of phosphorus application at @ 75 kg  $P_2O_5ha^{-1}$  recorded maximum fresh (0.20 and 0.38 g) and dry weight (0.11 and 0.22 g) of root nodules at 45 and 60 DAS respectively, over rest of the phosphorus levels. While, minimum fresh (0.16 g) and dry weight (0.07 g) was recorded with no application of phosphorus at 45 DAS. Similar trend in fresh and dry weight of nodule per plant was also noticed at 60 DAS. The interaction effect of phosphates solubilizing microorganisms and phosphorus levels showed non-significant effect on fresh weight at 45 DAS and dry weight at 45 and 60 DAS. However, it was showed significant effect on fresh weight of root nodules at 60 DAS only. Improvement in nodulation by the application of phosphate solubilizing microorganisms could be attributed to a greater solubility and availability of phosphate, which is essential for nodule development (Paratey Wani *et al.*, 2005<sup>[10]</sup>). Similar results were also reported by Kumawat *et al.*, (2009)<sup>[04]</sup> and Singh *et al.*, (2018)<sup>[12]</sup>.

#### **Chlorophyll content:**

The data furnished in table 3 revealed that *Aspergillus awamori* recorded maximum chlorophylla, chlorophyll b and total chlorophyll (2.06, 1.02 and 3.08  $mgg^{-1}$ , respectively) at 45 DAS followed by *Aspergillus niger* (1.8, 0.92 and 2.70  $mgg^{-1}$  respectively) and *Bacillus megaterium* (1.52, 0.81 and 2.33  $mgg^{-1}$ ). Whereas, lowest values of chlorophylla, chlorophyll b and total chlorophyll content was found in control (1.03, 0.63 and 1.66  $mgg^{-1}$ ).

**Table3:Chlorophyllcontentasinfluencedby phosphatesolubilizing microorganisms and phosphatelevelsinchickpea.**

Phosphoruslevels( $P_2O_5$ kg $ha^{-1}$ )					
PSM	P0	P45	P60	P75	Mean
<b>Chlorophylla(mgg<math>^{-1}</math>)</b>					
T0	0.81	0.89	1.18	1.27	<b>1.03</b>
T1	1.33	1.46	1.60	1.71	<b>1.52</b>
T2	1.74	1.77	1.82	1.87	<b>1.80</b>
T3	1.93	1.92	2.15	2.24	<b>2.06</b>
Mean	<b>1.45</b>	<b>1.52</b>	<b>1.69</b>	<b>1.77</b>	
	T		P		TXP
SE	<b>0.01</b>		<b>0.01</b>		<b>0.02</b>
C.D at5%	<b>0.05</b>		<b>0.05</b>		<b>0.09</b>
<b>Chlorophyllb(mgg<math>^{-1}</math>)</b>					
T0	0.55	0.58	0.69	0.72	<b>0.63</b>
T1	0.78	0.79	0.82	0.86	<b>0.81</b>
T2	0.87	0.90	0.91	0.93	<b>0.90</b>
T3	0.97	0.94	0.99	1.22	<b>1.02</b>
Mean	<b>0.79</b>	<b>0.80</b>	<b>0.85</b>	<b>0.93</b>	
	T		P		TXP
SE	<b>0.009</b>		<b>0.009</b>		<b>0.01</b>
C.D at5%	<b>0.02</b>		<b>0.02</b>		<b>0.05</b>
<b>Totalchlorophyll(mgg<math>^{-1}</math>)</b>					
Phosphoruslevels( $P_2O_5$ kg $ha^{-1}$ )					
PSM	P0	P45	P60	P75	Mean
T0	1.36	1.47	1.87	1.99	<b>1.67</b>
T1	2.11	2.25	2.43	2.57	<b>2.33</b>
T2	2.61	2.72	2.80	2.90	<b>2.70</b>
T3	2.86	2.80	3.46	2.43	<b>3.08</b>
Mean	<b>2.24</b>	<b>2.32</b>	<b>2.46</b>	<b>2.70</b>	
	T		P		TXP
SE	<b>0.04</b>		<b>0.04</b>		<b>0.08</b>
C.D at5%	<b>0.12</b>		<b>0.12</b>		<b>0.25</b>

The application of phosphorus @ 75 kg  $P_2O_5$   $ha^{-1}$  was influenced significantly and recorded maximum values of chlorophyll a, chlorophyll b and total chlorophyll content (1.77, 0.93 and 2.70 mg  $g^{-1}$  respectively) in chickpea (Table 6 and fig. 1). While minimum values of chlorophyll a, chlorophyll b and total chlorophyll content was found in control (i.e. 1.45, 0.79 and 2.24 mg  $g^{-1}$ ). The combined effect of *Aspergillus awamori* and application of phosphorus @ 75 kg  $P_2O_5$   $ha^{-1}$  showed highest chlorophyll a, chlorophyll b and total chlorophyll content. The

application of higher dose of phosphorus in combination of phosphates solubilizing microorganisms increased the chlorophyll content in leaves of chickpea might be ascribed to increase the solubility of phosphorus in the root environment thereby more utilization of phosphorus by plant for their growth and metabolic activity (Kumawat *et al.* 2009) <sup>[04]</sup>.

#### Seedyield:

The seedyield of chickpea as influenced by phosphates solubilizing microorganism narrated in table 4. The seed inoculation with *Aspergillus awamori* produced higher seedyield (1502.68 kg ha<sup>-1</sup>) as compared to application of *Aspergillus niger* (1406.6 kg ha<sup>-1</sup>) and *Bacillus megaterium* (1344.53 kg ha<sup>-1</sup>). Significant improvement in yield was noticed with the application of different phosphorus levels. Among the different phosphorus levels application of phosphorus @ 75 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> recorded higher seed yield (1451.0 kg ha<sup>-1</sup>) as compared to application of phosphorus @ 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> (1403.25 kg ha<sup>-1</sup>) and 45 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> (1346.18 kg ha<sup>-1</sup>). While, minimum seedyield was recorded in control (1322.77 kg ha<sup>-1</sup>).

**Table 4: Seedyield of chickpea as influenced by phosphate solubilizing microorganisms and phosphorus levels.**

PSM	Phosphorus levels (P <sub>2</sub> O <sub>5</sub> kg ha <sup>-1</sup> )				Mean
	P0	P45	P60	P75	
	Seed Yield kg ha <sup>-1</sup>				
<b>T0</b>	1198.85	1232.67	1303.35	1342.52	<b>1269.35</b>
<b>T1</b>	1344.64	1308.21	1354.48	1370.79	<b>1344.53</b>
<b>T2</b>	1345.15	1401.31	1416.74	1463.33	<b>1406.63</b>
<b>T3</b>	1402.44	1442.52	1538.42	1627.34	<b>1502.68</b>
<b>Mean</b>	<b>1322.77</b>	<b>1346.18</b>	<b>1403.25</b>	<b>1451.00</b>	
	<b>T</b>		<b>P</b>		<b>TXP</b>
<b>SE</b>	<b>12.59</b>		<b>12.59</b>		<b>25.18</b>
<b>C.D at 5%</b>	<b>36.35</b>		<b>36.35</b>		<b>72.71</b>

Interaction between phosphates solubilizing microorganisms and phosphorus levels was found to be significant. The seed inoculation with *Aspergillus awamori* and application of phosphorus @ 75 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> recorded highest value of seed yield than rest of the interactions. This may be attributed to *Aspergillus awamori* increase more values of growth parameters at almost all growth stages and helped in reducing P fixation by its chelating effect and also solubilized the unavailable form of P leading to more uptake of nutrients resulted in better growth of the plant (Das *et al.*,

2013)<sup>[01]</sup>.The increase in seed yield due to increase in P level may be attributed to increase in the availability of P in soil. Similar findings are noted by Nawange *et al.* (2011)<sup>[08]</sup>.

**Straw Yield:**

It is evidenced from the data presented in table 5. The straw yield of chickpea as significantly influenced by phosphate solubilizing microorganism, The seed inoculation with *Aspergillus awamori* produced maximum straw yield of chickpea (1803.2 kg ha<sup>-1</sup>) as compared to application of *Aspergillus niger* (1688.0 kg ha<sup>-1</sup>) and *Bacillus megaterium* (1613.4 kg ha<sup>-1</sup>). Among the different phosphorus levels application of phosphorus @ 75 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> recorded higher straw yield (1741.19 kg ha<sup>-1</sup>) as compare to application of phosphorus @ 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> (1683.90 kg ha<sup>-1</sup>) and 45 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> (1615.41 kg ha<sup>-1</sup>). However, the minimum straw yield was recorded in control (1587.32 kg ha<sup>-1</sup>). Interaction between phosphate solubilizing microorganisms and different phosphorus levels on straw yield was found to be significant. The seed inoculation with *Aspergillus awamori* and application of phosphorus @ 75 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> recorded higher value of straw yield than rest of the interactions. This was mainly due to the fact that *Aspergillus awamori* and application of phosphorus @ 75 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> increase in the availability of N and P caused better root development, better growth and development of plants and better diversion of photosynthate toward sink Tagore *et al.*, (2013)<sup>[13]</sup>. Kumar *et al.*, (2019)<sup>[03]</sup> reported that the straw yield of chickpea increased due to increase in phosphorus levels might be because of increase in the microbial activity in the root environment which accelerates cell division and formation of meristem.

**Table 5: Straw yield as influenced by phosphate solubilizing microorganisms and phosphorus levels in chickpea.**

PSM	Phosphorus levels (kg P <sub>2</sub> O <sub>5</sub> ha <sup>-1</sup> )				
	P0	P45	P60	P75	Mean
	Straw Yield kg ha <sup>-1</sup>				
T0	1438.6	1479.2	1564.0	1611.0	<b>1523.2</b>
T1	1613.6	1569.8	1625.4	1644.9	<b>1613.4</b>
T2	1614.2	1681.6	1700.1	1756.0	<b>1688.0</b>
T3	1682.9	1731.0	1846.1	1952.8	<b>1803.2</b>

<b>Mean</b>	<b>1587.32</b>	<b>1615.41</b>	<b>1683.90</b>	<b>1741.19</b>	
	<b>T</b>		<b>P</b>		<b>TXP</b>
<b>SE</b>	<b>15.11</b>		<b>15.11</b>		<b>30.22</b>
<b>C.D at5%</b>	<b>43.63</b>		<b>43.63</b>		<b>87.26</b>

#### Protein Yield:

The data pertaining to protein content and protein yield influenced significantly and presented in table 6. The maximum protein yield ( $426.96 \text{ kg ha}^{-1}$ ) and protein content (23.62 %) was recorded with seed inoculation of *Aspergillus awamori* followed by *Aspergillus niger* ( $392.47 \text{ kg ha}^{-1}$  and 23.24% respectively) and *Bacillus megaterium* ( $362.27$  and 22.42% respectively). Whereas minimum protein yield ( $312 \text{ kg ha}^{-1}$ ) and protein content (23.62%) was recorded in control. The data on effect of different levels of phosphorus application shows that maximum protein yield and protein content was noticed with the application of phosphorus @  $75 \text{ P}_2\text{O}_5 \text{ kg ha}^{-1}$  ( $412.15 \text{ kg ha}^{-1}$  and 23.62% respectively). The grain yield and protein content reduced significantly with decrement in phosphorus levels upto application of phosphorus @  $60 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$  ( $378.87 \text{ kg ha}^{-1}$  and 22.44%) and  $45 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$  ( $344.48 \text{ kg ha}^{-1}$  and 21.25 %). The minimum protein yield ( $357.26 \text{ kg ha}^{-1}$ ) and protein content (22.38%) was recorded with no application of phosphorus.

**Table 6: Protein content and protein yield as influenced by phosphate solubilizing microorganism and phosphorus levels in chickpea.**

PSM	Phosphorus levels ( $\text{kg P}_2\text{O}_5 \text{ ha}^{-1}$ )				Mean
	P0	P45	P60	P75	
	<b>Protein Content (%)</b>				
<b>T0</b>	18.92	19.97	20.71	22.04	<b>20.41</b>
<b>T1</b>	22.21	20.84	23.30	23.33	<b>22.42</b>
<b>T2</b>	24.16	22.75	22.43	23.63	<b>23.24</b>
<b>T3</b>	24.21	21.46	23.33	25.47	<b>23.62</b>
<b>Mean</b>	<b>22.38</b>	<b>21.25</b>	<b>22.44</b>	<b>23.62</b>	
	<b>T</b>		<b>P</b>		<b>TXP</b>
<b>SE</b>	<b>0.12</b>		<b>0.12</b>		<b>0.25</b>
<b>C.D at5%</b>	<b>0.36</b>		<b>0.36</b>		<b>0.73</b>
	<b>Protein Yield (<math>\text{kg ha}^{-1}</math>)</b>				
<b>T0</b>	272.68	295.78	324.31	355.47	<b>312.06</b>
<b>T1</b>	358.61	327.56	378.88	384.05	<b>362.27</b>
<b>T2</b>	390.20	382.92	381.46	415.32	<b>392.47</b>
<b>T3</b>	407.57	371.66	430.85	497.77	<b>426.96</b>

<b>Mean</b>	<b>357.26</b>	<b>344.48</b>	<b>378.87</b>	<b>413.15</b>	
	<b>T</b>		<b>P</b>		<b>TXP</b>
<b>SE</b>	<b>3.04</b>		<b>3.04</b>		<b>6.09</b>
<b>C.D at5%</b>	<b>8.80</b>		<b>8.80</b>		<b>17.60</b>

The interaction effect of phosphatesolubilizing microorganisms and phosphorus levels shows significant effect on protein yield and protein content. This may be due to both nutrients playing a main role in protein metabolism. Similarly, an increase in protein content in seed due to application of phosphorus resembles an increase in higher uptake of N by plant which is a main constituent of amino acid and building block of protein. Similar results are also noted by Miretal., (2013)<sup>[05]</sup> and Singh et al., (2018)<sup>[12]</sup>.

#### **Test Weight:**

The data furnished in table 7 revealed that the high value of test weight (158.00g) was recorded with seed inoculation of *Aspergillus awamori* followed by *Aspergillus niger* (157.62g) and *Bacillus megaterium* (157.14g). The minimum test weight (156.99g) was noticed in control. The application of @ 75 kg P<sub>2</sub>O<sub>5</sub>ha<sup>-1</sup> recorded maximum test weight (158.49 g), followed by application of 60 kg P<sub>2</sub>O<sub>5</sub>ha<sup>-1</sup> (157.71g) and 45 kg P<sub>2</sub>O<sub>5</sub>ha<sup>-1</sup> (156.49 g). The combined effect of phosphatesolubilizing microorganisms and varied levels of phosphorus influenced and the increase in test weight due to combined application of phosphatesolubilizing microorganisms and phosphorus levels attribute to increase in the symbiotic nitrogen fixation by adding more phosphorus which help to seeds for their development and ultimately increase the size of seed (Tagore et al., 2013)<sup>[13]</sup>. These findings are in line with the findings reported Prajapati et al., (2017)<sup>[11]</sup>.

**Table 7: Test weight of chickpea seed as influenced by phosphatesolubilizing microorganisms and phosphorus levels.**

PSM	Phosphorus levels (P <sub>2</sub> O <sub>5</sub> ha <sup>-1</sup> )				Mean
	P0	P45	P60	P75	
<b>Test Weight (g)</b>					
<b>T0</b>	156.35	157.59	156.77	157.27	<b>156.99</b>
<b>T1</b>	155.88	156.86	157.70	158.13	<b>157.14</b>
<b>T2</b>	155.94	157.37	158.14	159.04	<b>157.62</b>
<b>T3</b>	157.77	156.45	158.25	159.51	<b>158.00</b>
<b>Mean</b>	<b>156.49</b>	<b>157.07</b>	<b>157.71</b>	<b>158.49</b>	
	<b>T</b>		<b>P</b>		<b>TXP</b>
<b>SE</b>	<b>0.07</b>		<b>0.07</b>		<b>0.15</b>
<b>C.D at5%</b>	<b>0.21</b>		<b>0.21</b>		<b>0.43</b>

### Conclusion

It can be inferred and concluded that , incorporation of phosphatesolubilizing microorganisms viz. *Aspergillus awamori* in combination with application of phosphorus @ 75 kg P<sub>2</sub>O<sub>5</sub>ha<sup>-1</sup> improved growth attributes, yield attributes and quality of chickpea.

### References

1. Das, S., Pareek, B.L., Kumavat, A. and Dhikwal, S.R. (2013) Effect of phosphorus and biofertilizers on production of chickpea (*Cicer arietinum* L.) in north western Rajasthan, *Ind. Legume. Res.* 36(6): 511- 514.
2. Jain R., Saxena J., Sharma V. (2010). The evaluation of free and encapsulated *Aspergillus awamori* for phosphate solubilization in fermentation and soil-plan system. *App. Soil. Eco.* 46, 90-94.
3. Kumar, J. Kumar, S. and Prakash V. (2019) effect of biofertilizers and phosphorus levels on soil fertility yield and nodulation in chickpea (*Cicer arietinum* L.). *J. Ind.Soci. Soil. Sci.* 67 (2):199-203.
4. Kumawat, N., Sharma, O.P., Kumar, R. and Kumari, A. (2009). Response of organic manures, PSB and phosphorus fertilization on growth and yield of mungbean. *Envi. Eco.* 27(4): 2024-2027.
5. Mir, A.H., Lal, S.B., Salmani, M. Abid, M. and Khan, I. (2013) Growth, yield and nutrient content of blackgram (*vigna mungo*) as influenced by levels of phosphorus, sulphur and phosphorus solubilizing bacteria. *SAARC. J. Agri.*, 11(1): 1-66.
6. Mittal, V., Singh, O., Nayyar, H., Kaur, J. and Tewari, R. (2008). Stimulatory effect of phosphate-solubilizing fungal strains (*Aspergillus awamori* and *Penicillium citrinum*) on the yield of chickpea (*Cicer arietinum* L. cv. GPF2). *Soil. Bio. Bioche.* (40) 718-727.
7. Narsihan, V., Patel, H.H. (2000). *Aspergillus aculeatus* as a rock phosphate solubilizer. *Soil. Bio. Bioche.* (32):559-565.
8. Nawange, D.D., Yadav, A.S. and Singh, R.V. (2011). Effect of phosphorus and sulphur application on growth, yield attributes and yield of chickpea (*Cicer arietinum* L.). *Legume. Res.* 34(1):48-50.
9. Panse VG, Sukhatme PK. (1985) Statistical methods for agriculture workers, (IV Edn.) ICAR, New Delhi. 1985, 145-156.

**Comment [sd5]:** References are insufficient. Make it up to 25-30

10. Paratey, P.R. And Wani, P.V. (2005). Response of soybean to phosphate solubilizing biofertilizers. *Legume .Res.* 28(4): 268-271.
11. Prajapati, B.J., Gudadhe, N. Gamit, V.R. and Chhaganiya, H.J. (2018). Effect of integrated phosphorus management on growth, yield attributes and yield of chickpea. *Fmg. &Mngmt.* 2(1): 36-40.
12. Singh, R. Singh, P. Singh, V. and Yadav, R.A. (2018). Effect of phosphorus and PSB on growth parameters, yield, quality and economics of summer greengram (*Vigna radiata* L.) *Int. J. Chem. Stud.* 6(4): 2798-2803.
13. Tagore, G.S., Namdeo, S.L., Sharma, S.K. and Kumar, N. (2013). Effect of *Rhizobium* and Phosphate Solubilizing Bacterial Inoculants on Symbiotic Traits, Nodule Leghemoglobin, and Yield of Chickpea Genotypes. *Int. J. Agron.* 8:581627.
14. Vidhyashree, V., Naga, S.R., Yadav, B.L., Koli D.K. and Rao I.J. (2017). Effect of phosphorus and biofertilizers on growth and yield of mungbean [*Vigna radiata* (L.)Wilczek]. *Int. J. Curr. Micro. App. Sci.* 6(7): 3992- 3997.