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Yield and yield attributes of Mungbean (*Vigna radiata* L.) cultivars as affected by phosphorous levels under different tillage systems

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Yield and yield attributes of Mungbean (*Vigna radiata* L.) cultivars as affected by phosphorous levels under different tillage systems

Imran[1]*, Asad Ali Khan[1], Inamullah Inam[1] and Fayaz Ahmad[1]

Abstract: Two mungbean cultivars, Swat-1 and NM-98, four levels of phosphorous (0, 20, 40, and 60 kg ha^{-1}) in the form of TSP, and four tillage systems, zero tillage (no tillage), minimum tillage (2-time), conventional tillage (4-time), and maximum tillage (6-time) were used. Results divulge that plant height, number of pods plant^{-1}, number of seeds pod^{-1}, biological yield, seed yield, 1,000 seed weight, harvest index, and protein content were significantly affected by mungbean cultivars, various phosphorous levels, and tillage systems. Cultivar swat-1 stands first in term of growth and yield. Highest thousand seed weight, seed yield, biological yield, and harvest index % were produced by P at the rate of 60 kg ha^{-1}, while maximum plant height, number of pods plant^{-1}, number of seeds pod^{-1}, and protein content were given by P at the rate of 40 kg ha^{-1} at par with P at the rate of 60 kg ha^{-1}. Among different tillage systems, maximum number of pods plant^{-1}, 1,000 seed weight, biological yield, seed yield, and protein content were observed in maximum tillage system. In case of interaction between P × T, maximum pods plant^{-1}, 1,000 seed weight, biological yield, seed yield, and protein content were produced by 60 kg P ha^{-1} + maximum tillage system.

Subjects: Agriculture & Environmental Sciences; Bioscience; Environment & Agriculture; Soil Sciences

Keywords: Mungbean (*Vigna radiata* L.); cultivar; P; tillage system; grain yield; yield components

ABOUT THE AUTHOR

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Imran

PUBLIC INTEREST STATEMENT

Mungbean has high nutritive value, and due to this, has advantage over the other pulses known as king of the pulse crop. The seed contains 24.20% protein content, 1.30% fat, and 60.4% carbohydrates; calcium (Ca) is 118 and phosphorus (P) is 340 mg per 100 g of seed. Pulses are known as poor man's meat and cheap source of vegetable protein containing 20–25% protein. Its production is very low in many regions due to miss management of the inputs. Therefore, if farmers implement more number of tillage practices as compared to conventional, so the crop nutrients demand will be fulfilled by the leached and adsorbed nutrients, away from root zone by pulverizing the soil with more number of tillage, whereas the productivity of the soil will also increase with soft soil, promote root density, and will result in more number of nodules having more nitrogen fixation.

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1. Introduction

Mungbean (*Vigna radiata* L.) is an important conventional pulse crop of Pakistan and commonly known as green gram. It has high nutritive value, and due to this, has advantage over the other pulses. The seed contains 24.20% protein content, 1.30% fat, and 60.4% carbohydrates; calcium (Ca) is 118 and phosphorus (P) is 340 mg per 100 g of seed, respectively (Imran et al., 2015). It fixes atmospheric nitrogen through *Rhizobium* species. *Rhizobium* species in the presence of phosphorus not only fix more nitrogen through increased number of nodules but the protein contents, dry matter, and seed yield of various legume crops also increased to considerable extent. Pulses are known as poor man's meat and cheap source of vegetable protein containing 20–25% protein. The Mungbean (*Vigna radiata*) is esteemed among the entire pulse species because it is an easily digestible pulse. Production of mungbean has remained static during the last decade; as a result, the gap between supply and demand is widening (Imran et al., 2015). Its average yield in Pakistan is 461.5 kg ha^{-1} and total seed production is 91.2 thousand tones (Anonymous, 1998), which is much lower the harvested potential of our existing varieties. Area under cultivation of mungbean in Pakistan is 197.6 thousand hectares. Therefore, it is necessary to advance the weak chains of crop production lays emphasis on the judicious use of artificial/commercial fertilizer to ensure a rich crop harvest. Mungbean is naturally nodulation crop to some extent and the degree of nodulation varies with the area and culture being used. Being a legume crop, it necessitates less nitrogen but phosphorus application is an important input for higher yields per unit area. Energy storage and transfer are the most essential functions of P in plant growth. It is an important structural component of a wide variety of biochemicals, including nucleic acid, nucleotides, phosphor-proteins, phospholipids, and sugar phosphate (Havlin, Beaton, Tisdule, & Nelson, 2004). Various levels of applied P significantly affected the growth and yield components of mungbean (Khan, Asif, Hussain, & Aziz, 2003). Sharma and Singh (1993) reported that phosphorus applications increased green gram seed yield and protein content (Sharma & Singh, 1993). Tillage is the mechanical manipulation of the soil. Tillage operations are done to prepare seedbed for sowing, improve soil physical structure, and to control weed. Conventional tillage system is used to prepare seedbed. It requires more energy as fuel and consumes more time. But the concept of zero tillage and minimum tillage requires less fuel, preserves moisture, and saves time for timely cultivation. In zero tillage system, the soil is left undisturbed from harvest to seeding and seeding to harvest (Thiagalingam et al., 1996). Zero tillage and minimum tillage system may have beneficial impact on seed yield and minimize the environmental degradation such as soil erosion (Armstrong, Millar, Halpin, Reid, & Standley, 2003). Mungbean sown with zero tillage and adequate vegetative mulch on the soil surface gave high yield comparable with, or even higher than those obtained under conventional tillage (Thiagalingam et al., 1996). Keeping in view the above facts, therefore, present study was designed to evaluate the response of mungbean cultivars to different levels of phosphorus and different tillage systems for realizing the maximum yield potential under the agro-ecological conditions of swat valley.

2. Materials and methods

To study the response of mungbean cultivars to various phosphorous levels under different tillage system, field experiments were consecutively conducted at Agriculture Research Institute, (N) Mingora Swat, Pakistan, during summer 2012 and 2013 (two-years consecutive study). The experimental design used was randomized complete block (RCB) design with three replications. Two mungbean cultivars Swat-1 and NM-98, four levels of phosphorous (0, 20, 40, and 60 kg ha^{-1}) in the form of triple super phosphate (TSP), and four tillage systems, zero tillage (no tillage), minimum tillage (2-time), conventional tillage (4-time), and maximum tillage (6-time) were used. A plot size of 5 × 3 m was used. Subplot was consisted of six rows having 50 cm row-to-row distance with row length of 5 m. Nitrogen in the form of urea was applied at the rate of 25 kg ha^{-1} as a starter dose during seedbed preparation. All the recommended agronomic practices like weeding, hoeing, irrigation, and other cultural practices were followed. Data were recorded on plant height, number of pods plant^{-1}, number of seed pod^{-1}, biological yield, seed yield, 1,000 seed weight, harvest index %, and protein content. Plant height was measured at the harvesting stage. Plant height from the ground level to the apex of the five randomly selected plants in each subplot was measured through measuring tape and averaged. After threshing, data on thousand seeds weight (g) were recorded from

three seed lot and weighted with the help of electronic balance. Four central rows in each subplot were harvested, sun dried, and threshed. Seed weight was taken with the help of electronic balance and then converted into kg ha^{-1} using the following formula:

$$\text{Seed yield}\left(\text{kg ha}^{-1}\right) = \frac{\text{Seed weight in four rows}}{\text{R - R distance} \ \times \ \text{row length} \ \times \ \text{No of rows}} \times 10000$$

Biological yield was calculated using the following formula:

$$\text{Biological yield}\left(\text{kg ha}^{-1}\right) = \frac{\text{Number of plants}}{\text{R - R distance} \ \times \ \text{row length} \ \times \ \text{No of rows}} \times 10000$$

Harvest index was calculated using the following formula:

$$\text{Harvest Index}(\%) = \frac{\text{Seed yield (kg ha} - 1)}{\text{Biological yield (kg ha} - 1)} \times 100$$

Collected data were analyzed statistically through statistical package (statistix 8.1) according to the procedure relevant to three factorial RCB design. Least significant difference (LSD $p \leq 0.05$) test was used for mean comparison to identify the significant components of the treatment means (Jan, Shah, Hollington, Khan, & Sohail, 2009).

3. Results and discussion

3.1. Plant height (cm)
Perusal of the data indicated that cultivars, P levels, and tillage systems significantly affected the plant height. Interaction between P × T significantly affected the plant height, while other interactive effects between C × P, C × T, and C × P × T were found non-significant. Mean value showed that the maximum plant height was recorded in cultivar Swat-1 (54.6 cm) followed by NM-98 (52.6 cm) during the year 2012. In next year (2013), both cultivars were statistically at par having 53.3 and 53.4 cm plant height. In case of P levels, the maximum plant height was recorded in plot received P at the rate of 60 and 40 kg ha^{-1} (54.8 and 54.7 cm), while minimum plant height was noted in the control plot in the year 2012, while during next year (2013), the same results were noted again and the highest plant height was recorded in plots treated with 60 and 40 kg P ha^{-1}, but the results were statistically at par with 20 kg and 60 kg P ha^{-1}. This might be due to more uptake of P which enhances root penetration and density with the results of more BNF and used by the plant for self-sustainability and development. These findings are with conformity of those reported by Iqbal, Khan, and Shaheen (2012) and (Imran et al., 2015); they observed that the maximum plant height was recorded in the plot treated with 90 kg P ha^{-1} having at par with 60 kg ha^{-1}. Similarly, tillage system significantly affected the plant height, and the maximum plant height was noted in conventional tillage, which was statistically at par with maximum tillage system (54.6 and 54.7 cm), while minimum plant height was recorded in minimum tillage system having at par with the control plot (51.7 and 52.3 cm). In the next year experiment (2013), the maximum plant height was found in maximum tillage followed by conventional tillage but having statistically at par value (55.3 and 53.8 cm). Shortest plant height was observed in no tillage practice plots having at par with minimum tillage (52.3 and 51.6 cm), respectively. The reason could be better soil physical condition and well-pulverized soil for root penetration to uptake optimum nutrients. The findings of these results are connected with those of Yusuf, Siemens, and Bullock (1999) and (Imran et al., 2015) who described that plants grown with conventional tillage are taller than zero tillage. In case of interaction, conventional tillage with P at the rate of 60 kg ha^{-1} gave the highest plant height (59.8 cm), whereas the minimum plant height was recorded in minimum tillage system with no P application (50.3 cm). These results are with conformity of those of Iqbal et al. (2012); they stated that conventional tillage + 90 kg P gave the highest plant height.

3.2. Number of pods plant^{-1}
Analysis of the data showed that cultivars, P levels, and tillage systems significantly affected number of pods plant^{-1}. Interaction between P × T significantly affected number of pods plant^{-1}, while

other interactive effects of C × P, C × T, and C × P × T were found non-significant. Mean value of the data divulges that maximum pods plant^{-1} produced by cultivar Swat-1 (19.2) followed by NM-98 (17.8) during 2012, while in next year cultivar, swat 1 produced 19.4 pods plant^{-1} followed by NM-98 having 18.2 pods plant^{-1}. This might be due to genetic superiority. P levels significantly affected pods number in the year 2012 and maximum pods plant^{-1} produced by the plot treated with 60 kg ha^{-1} having at par with 40 kg P ha^{-1} treated plot (20.6 and 20.0), whereas minimum pods plant^{-1} were recorded in the control plot (16.0). In the year 2013, maximum pods plant^{-1} (20.8) were recorded in plots treated with P at the rate of 60 kg ha^{-1} followed by 40 kg ha^{-1} (19.3). Increase in pods number with P application was also reported by Iqbal et al. (2012) and Balachandran and Sasidhar (1991) who observed increase in pods number with P levels. In case of tillage system, maximum pods plant^{-1} were observed in maximum tillage (6-time) having 23.0 pods plant^{-1} in 2012 and 22.9 pods plant^{-1} in the year 2013 followed by conventional tillage having 20.0 pods and 20.0 in both years although minimum pods plant^{-1} were observed in zero tillage system having 14.7 pods plant^{-1} during 2012 and 14.61 in the next year, respectively. The findings of the results are connected with Iqbal et al. (2012); they described that conventional tillage gave maximum pods plant^{-1}. The interaction between P × T was found highly significant. Maximum numbers of pods were observed in maximum tillage with the application of 60 kg P ha^{-1} (28) followed by conventional tillage with the application of 60 kg P ha^{-1} (25.5), whereas minimum pods were recorded in zero tillage + no P (control) having 13.6 pods plant^{-1}. These results are agreed with those of Shafiq, Hassan, Ahmad, and Rashid (1994), Imran et al. (2015), and Iqbal et al. (2012); they stated that maximum number of pods plant^{-1} and other yield contributing parameters can be obtained with the application of optimum fertilization and better tillage practices.

3.3. Number of seeds pod^{-1}

Analyzed data divulge that number of seeds pod^{-1} significantly affected by cultivars, P levels, and tillage system, whereas all the interaction was non-significant in this order. The data showed that highest seeds pod^{-1} were noted in cultivar swat-1 (11.1) followed by the other sown cultivar NM-98 (9.2) in the year 2012. In the next year, seeds pod^{-1} varied in both cultivars, and 12.16 seeds pod^{-1} were recorded in cultivars Swat-1 and 11.6 in NM-98 in the year 2013. The reason could be genetic superiority having high yielding characteristics. P levels significantly affected the number of seeds pod^{-1}, and the maximum seeds pod^{-1} were recorded in 60-kg P ha^{-1}-treated plots (10.9) having at par value with 40 kg P ha^{-1} having (10.8) number of seeds pod^{-1} during the first year, while maximum (11.2) seeds pod^{-1} were noted again in the next year in plots treated with 60 kg P ha^{-1} followed by 40 kg P ha^{-1} (10.9 seeds). Minimum seeds pod^{-1} (9.1) were counted in the control plot having at par value with 20 kg P ha^{-1}. These results are agreed with conformity of Dubey, Sinha, and Yadva (1993) and Iqbal et al. (2012); they described that number of seeds pod^{-1} was increased with increase in P levels. Similarly, in case of tillage system, during 2012, maximum number of seeds pod^{-1} was noted in maximum tillage (11.3 seeds) but statistically at par with conventional tillage system having (10.7) seeds pod^{-1}, while minimum seeds pod^{-1} was recorded in zero tillage (8.8 seeds). The same position was seen again during 2013, and maximum seeds (11.4) were retained by maximum tillage-practiced plot followed by at par (10.8) conventional tillage-practiced plot, whereas minimum seeds pod^{-1} (8.9) were counted in zero tillage-practiced plots, respectively. These findings are also reported by Zamir (2006) who concluded that number of seeds pod^{-1} was enhanced with conventional tillage system.

3.4. Biological yield (kg ha^{-1})

Perusal of the data indicated that cultivars, P levels, tillage, and interaction between P × T significantly affected biological yield, while interaction of C × P, C × T, and C × P × T was non-significant. The result showed that cultivar Swat-1 produced maximum biological yield (3,441.5 kg ha^{-1}) followed by the other sown cultivars NM-98 (3,235.7 kg ha^{-1}) in the year 2012, whereas the same cultivars Swat-1 produced 3,510.7 and NM-98 3,285.9 kg biological yield in the year 2013. Among P levels, maximum biological yield in the year 2012 was observed with 60 kg P ha^{-1} (3,642.3 kg ha^{-1}) followed by 40 kg P ha^{-1} (3,432.3 kg ha^{-1}), whereas minimum biological yield was recorded in the control plot (3,097.4 kg ha^{-1}) but statistically at par with 20-kg P ha^{-1}-treated plot having 3,182.3 kg ha^{-1}

biological yield. In the year 2013, the same position was sustained and maximum (3,710.8 kg) biological yield was recorded in plots treated with 60 kg P ha⁻¹ followed by 40 kg P ha⁻¹ application. The results are closely associated with those of Shafiq et al. (1994) and Jamshidian and Khajehpour (1999); they reported substantial result of P on biological yield of mungbean. Correspondingly, tillage systems also significantly affected biological yield in the year 2012 and in 2013. Highest biological yield was noted in maximum tillage-practiced plot (3,680.3 kg ha⁻¹) followed by conventional tillage (3,405.0 kg ha⁻¹), whereas minimum biological yield was recorded in zero tillage system (3,086.5 kg ha⁻¹) but statistically at par with minimum tillage having (3,182.5 kg ha⁻¹) biological yield. In the year 2013, a linear increase was noted in biological yield with fluctuation in tillage systems, and maximum biological yield (3,684.4 kg) was recorded in maximum tillage, followed by conventional tillage system (3,399.9 kg) and minimum tillage (3,183.4 kg), respectively. These results are against with those of Zamir (2006) and Iqbal et al. (2012); they described that conventional tillage and minimum tillage systems gave at par-valued biological yield. In case of interaction between P × T, maximum biological yield was observed in treatment of maximum tillage with 60 kg P ha⁻¹ followed by conventional tillage with 60 kg P ha⁻¹ (4,341.3 and 3,880.0 kg ha⁻¹); however, lowest biological yield was noted in treatment zero tillage with no P application (3,041.7 kg ha⁻¹). The findings of these results are related with conformity with those of Zamir (2006) and Iqbal et al. (2012); they stated that conventional tillage + P level at the rate of 90 kg ha⁻¹ and minimum tillage systems + 90 kg P gave at par-valued biological yield.

3.5. Seed yield (kg ha⁻¹)

Seed yield showed that cultivars, P levels, tillage, and interaction between P × T significantly affected seed yield, while interaction of C × P, C × T and C × P × T was non-significant in term of seed yield. Mean value of the data showed that in the year 2012, maximum seed yield was recorded in cultivar Swat-1 (1,075.4 kg ha⁻¹) followed by the other sown cultivar NM-98 (962.6 kg ha⁻¹), while in the next year, seed yield enhanced in both cultivars. Cultivar Swat-1 produced 1,140.3 kg seed yield ha⁻¹ and NM-98 produced 987.4 kg seed yield ha⁻¹. Among P levels, maximum seed yield was noted in the year 2012 and in 2013 with 60-kg P ha⁻¹-treated plot (1,182.8 kg and 1,227.9 kg ha⁻¹) followed by 40-kg P ha⁻¹-treated plot (1,045.8 kg and 1,057.2 kg ha⁻¹) but statistically at par with 20 kg P ha⁻¹ (998.8 kg and 1,014.7 kg ha⁻¹), while minimum seed yield was noted in the control plot (848.6 kg and 847.9 kg ha⁻¹). The results are associated with conformity of Khan et al. (2003); they divulge that seed yield was enhanced with enhancement in the P levels. Results showed that tillage system significantly affected seed yield. Maximum seed yield was recorded in maximum tillage (1,221.8 kg ha⁻¹) followed by conventional tillage (1,071.0 kg ha⁻¹) although minimum seed yield was noted in zero tillage (839.5 kg ha⁻¹) during the first year experiment. In the year 2013, a linear increase was recorded in seed yield with increase in tillage operations. Maximum seed yield (1,242.7 kg) produced by maximum tillage-practiced plot followed by conventional and minimum tillage practices (1,075 kg and 947.7 kg), while minimum seed yield was noted in no tillage practice plot (841.4 kg), respectively. This finding of the results supported by Imran et al. (2015) and Iqbal et al. (2012) who reported that tillage system had significant effect on seed yield of mungbean. Interaction between P × T divulges that highest seed yield was given by maximum tillage + 60 kg P ha⁻¹ (1,493.0 kg ha⁻¹) followed by conventional tillage + 60 kg P ha⁻¹ (1,259.2 kg ha⁻¹). Minimum seed yield was noted in zero tillage with no P application (741.7 kg ha⁻¹). These results are closely associated with those of Shafiq et al. (1994), Imran et al. (2015), and Jamshidian et al.; they perceived that seed yield was enhanced with conventional tillage with the application of 90-kg P ha⁻¹-treated plot.

3.6. Thousand Seed weight (gm)

Perusal of thousand seed weight indicated that cultivars, P levels, tillage systems, and interaction between C × T and P × T significantly affected 1,000 seed weight. Mean data indicated that cultivar swat-1 attained maximum 1,000 seed weight than cultivar NM-98 (50.5 and 48.7 gm) in the year 2012, whereas in the year 2013, both cultivars produced statistically at par-valued thousand seed weight (50.4 and 49.8 gm) having no statistical differences, respectively. P levels result showed that maximum 1,000 seed weight was recorded in plot treated with 60 kg ha⁻¹ (52.4 gm) followed by 40 kg P ha⁻¹ but statistically at par with the control plot and 20 kg P ha⁻¹ (47.7 and 49.1 gm). In the

year 2013, maximum 1,000 seed weight (51.6 g) was recorded in plots treated with 60 kg P ha^{-1}, while lowest 1,000 seed weight (46.96 gm) was noted in the control plot, respectively. Increase in seed weight with P levels shows a direct positive contribution of P toward seed formation and development. These results confirmed by the finding of Khan et al. (2003); they determined that 1,000 seed weight increased with P levels. Similarly, tillage system divulges that in the year 2012, maximum 1,000 seed weight was observed in maximum tillage system (52.5 gm) followed by conventional tillage (49.1 gm), while minimum 1,000 seed weight was observed in minimum tillage system (47.2 gm), while in 2013, maximum 1,000 seed weight was recorded in maximum tillage practices (53.0 gm) followed by at par the other rest tillage practices having no statistical difference among them in respect of thousand seed yield (49.3, 48.2, and 49.5 gm). The results are in line with those of Iqbal et al. (2012). Interaction between C × T showed that cultivar swat-1 gave minimum 1,000 seed weight in zero tillage (51.5 gm) and cultivar NM-98 (47.5 gm), while maximum 1,000 seed weight in maximum tillage system gave by cultivar swat-1 (53.0 gm) and NM-98 (52.1 gm), respectively. In conventional tillage system, cultivar NM-98 gave maximum 1,000 seed weight than that of cultivar Swat-1 (50.0 and 48.3 gm). Interaction between P × T divulges that highest 1,000 seed weight was given by treatment maximum tillage + 60 kg P ha^{-1} followed by conventional tillage + 40 kg P ha^{-1} (56.8 and 51.5 gm). Thousand seed weight of conventional tillage system + 60 kg P ha^{-1} was statistically at par with that of maximum tillage + 40 kg P ha^{-1} (51.8 and 51.5 gm). Minimum 1,000 seed weight was observed in zero tillage + no P application (45.5 gm). These findings also reported by Iqbal et al. (2012); they testified that 1,000 seed weight was enhanced with tillage system and P levels.

3.7. Harvest index (%)

Analysis of the data showed that cultivars, P levels, and tillage systems significantly affected H.I %, whereas all the interaction was found non-significant. The data divulge that supreme H.I was recorded in cultivar swat-1 in the year 2012 and also in 2013 (30.9 and 31.4%) followed by the other sown cultivar NM-98 (29.4 and 29.2%). In case of P levels, maximum H.I was recorded in 60 kg P ha^{-1}-treated plot (32.1%) followed by 20 kg P ha^{-1} having at par value with 60 kg P ha^{-1} and 40 kg P ha^{-1} (31.1 and 30.0%), while minimum H.I was obtained by the control plot (27.5%) in the year 2012. In the year 2013, maximum H.I (31.9%) was noted with the application of 60 kg P ha^{-1} having at par valued with conventional and minimum tillage practices plots (30.3 and 30.1%), whereas lowest H.I was calculated in the control plot (27.8%). These findings are in conflict with the results of Iqbal et al. (2012) who reported that P has non-significant effect on H.I % of mungbean. Similarly, tillage system result in the year 2012 showed that maximum H.I was recorded in maximum tillage system (32.9%) followed by conventional tillage, but statistically at par with maximum tillage and minimum tillage (31.2 and 29.6%), while minimum H.I was recorded in zero tillage system (27.0%). In the year 2013, maximum H.I (33.1%) was recorded in maximum tillage-practiced plot, while lowest H.I was noted in zero tillage-practiced plot (27.1%). Maximum tillage and conventional tillage were at par valued (33.1 and 31.2%). Conventional and minimum tillage system also had at par value H.I (31.2 and 29.4%). These findings are closely related with those of Iqbal et al. (2012) and contrary with those of Zamir (2006).

3.8. Protein content (%)

Data regarding protein content (%) showed that cultivars, P levels, tillage system, and interaction between P × T significantly affected protein content. Data of protein content divulge that concentrated protein content was recorded in cultivar swat-1 (22.8%) followed by cultivar NM-98 (22.4%) in the year 2012, while having at par valued in the year 2013 (23.4 and 23.1%), respectively (Tables 1 and 2). Among P levels, maximum protein content was recorded in both years with 60 and 40-kg P ha^{-1}-applied plots having statistically at par (23.0 in the first year and 23.2 in the second year) in cultivar Swat-1 and (23.0 in the first year and 23.1% in the second year) in NM-98 followed by 20 kg P ha^{-1} (22.4%), whereas minimum protein content was noted in the control plot (22.0%), while in the year 2013, the control plot and 20-kg P-treated plot had at par-valued protein content (22.0 and 22.4%), respectively. The conformity of these results closely associated with those of Iqbal et al. (2012) who reported that protein content was enhanced with P levels. Similarly, tillage system

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Table 1. Plant height, number of pods plant^{-1}, number of seeds plant^{-1}, and biological yield of mungbean cultivars as affected by different phosphorous levels under different tillage systems

Years								
2012					**2013**			
Treatments	Plant height (cm)	No of pods plant^{-1}	No of seeds pod^{-1}	Biological yield (kg ha^{-1})	Plant height (cm)	No of pods plant^{-1}	No of seeds pod^{-1}	Biological yield (kg ha^{-1})
C1	54.62a	19.29a	11.10a	3,441.5a	53.37a	19.41a	12.16a	3,510.7a
C2	52.60b	17.85b	9.25b	3,235.7b	53.41a	18.24b	11.60b	3,285.9b
LSD Value (0.05)	1.24	0.73	0.49	68.85	1.17	0.84	0.49	71.37
P1	51.66b	16.04c	9.20b	3,097.4c	50.61b	15.97d	9.13b	3,192.2c
P2	54.79a	17.54b	9.75b	3,182.3c	53.74a	18.71b	9.71b	3,181.7c
P3	54.83a	20.04a	10.83a	3,432.3b	53.78a	19.37b	10.97a	3,541.4b
P4	53.16ab	20.66a	10.91a	3,642.3a	52.11ab	20.87a	11.26a	3,710.8a
LSD Value (0.05)	1.75	1.03	0.70	97.37	1.70	1.06	0.63	93.97
T1	52.33b	14.79d	8.87c	3,086.5c	52.37b	14.61d	8.97c	3,087.4d
T2	51.75b	16.37c	9.70b	3,182.5c	51.63b	15.97c	9.80b	3,183.4c
T3	54.62a	20.04b	10.75a	3,405.0b	53.87a	20.07b	10.85a	3,399.9b
T4	55.75a	23.08a	11.37a	3,680.3a	55.37a	22.97a	11.47a	3,684.4a
LSD Value (0.05)	1.75	1.03	0.70	97.37	1.65	1.04	0.73	96.32

Notes: C1: Swat-1, C2: NM-98; Four P levels (0, 20, 40 and 60 kg ha^{-1}); T1: zero tillage, T2: minimum tillage, T3: conventional tillage, T4: maximum tillage.

Means in the same category followed by different letters are significantly different at $p \leq 0.05$ levels, ns = non-significant.

Table 2. Seed yield (Kg ha^{-1}), thousand seed weight (gm), Harvest index (%) and protein content (%) of mungbean cultivars as affected by different phosphorous levels under different tillage systems

Years								
2012					**2013**			
Treatments	Seed yield (kg ha^{-1})	1,000 Seed weight (gm)	Harvest index (%)	Protein content (%)	Seed yield (kg ha^{-1})	1,000 Seed weight (gm)	Harvest index (%)	Protein content (%)
C1	1,075.4a	50.52a	30.97a	22.82a	1,140.3a	50.47a	31.47a	23.41a
C2	962.6b	48.72b	29.49b	22.45b	987.4b	49.84a	29.29b	23.10a
LSD Value (0.05)	41.86	1.24	1.37	0.30	42.31	1.24	1.47	0.39
P1	848.6c	47.70b	27.55c	22.02c	847.9c	46.96c	27.85b	22.06b
P2	998.8b	49.12b	31.12ab	22.48b	1,014.7b	48.47b	30.14a	22.42b
P3	1,045.8b	49.20b	30.09b	23.02a	1,057.2b	49.17b	30.37a	23.18a
P4	1,182.8a	52.45a	32.19a	23.01a	1,227.9a	51.63a	31.98a	23.27a
LSD Value (0.05)	59.20	1.75	1.94	0.43	61.37	1.47	1.97	0.38
T1	839.5d	49.54b	27.09c	21.61d	841.4d	49.51b	27.11c	21.66c
T2	943.6c	47.20c	29.60b	22.22c	947.7c	48.27b	29.47b	22.34b
T3	1,071.0b	49.16b	31.26ab	22.86b	1,075.0b	49.32b	31.24ab	23.81a
T4	1,221.8a	52.54a	32.98a	23.85a	1,242.7a	53.07a	33.15a	23.94a
LSD Value (0.05)	59.20	1.75	1.94	0.43	59.41	1.73	1.83	0.41

Notes: C1: Swat-1, C2: NM-98; Four P levels (0, 20, 40 and 60 kg ha^{-1}); T1: zero tillage, T2: minimum tillage, T3: conventional tillage, T4: maximum tillage.

Means in the same category followed by different letters are significantly different at $p \leq 0.05$ levels. ns = non-significant.

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Table 3. Interactive effect of years 2012 and 2013 of mungbean cultivars, different phosphorous levels, and tillage systems on yield and yield contributing parameters of mungbean

Treatments	Plant height (cm)	No of pods plant⁻¹	No of seeds pod⁻¹	Biological yield (kg ha⁻¹)	Seed yield (kg ha⁻¹)	1,000 Seed weight (gm)	Harvest index (%)	Protein content (%)
C × P	ns	ns	ns	ns	ns	ns	ns	ns
C × T	ns	ns	ns	ns	ns	*	ns	ns
P × T	*	*	ns	*	*	*	ns	*
C × P × T	ns	ns	ns	ns	ns	ns	ns	ns

significantly affected protein content and maximum protein was recorded in maximum tillage system followed by conventional tillage (23.8 and 22.8%), while minimum protein content was noted in zero tillage (21.6%) in the year 2012. In the year 2013, maximum protein content (23.9%) was noted in maximum tillage followed by at par-valued conventional tillage (23.8%), while the lowest protein was recorded in zero tillage-practiced plot (21.6%). The conformity of these results is closely connected with those of Iqbal et al. (2012) who reported that protein content was enhanced with conventional tillage system. The interactive effect of P × T was found significant and result showed that maximum protein content was recorded in maximum tillage + 60 kg P ha⁻¹ (24.9%) followed by conventional tillage + 40 kg P ha⁻¹ (24.5%), whereas minimum protein was noted in zero tillage + no P application (Table 3). These findings are closely related with those of Iqbal et al. (2012).

4. Conclusion and recommendations

More number of tillage practices enhanced root growth vertically and horizontally and promoted root penetration of mungbean. It was concluded on the basis of above results that mungbean cultivar "swat-1" stands first in term of growth, yield, and yield contributing parameters. Phosphorous levels and tillage system were applied in combination, P level at the rate of 60 kg ha⁻¹ with maximum tillage system (6-time) was found more effective for growth and yield of mungbean. It is recommended on the basis of above results that P level at the rate of 60 kg ha⁻¹ and maximum tillage system with sowing of cultivar swat-1 should be grown for profitable yield under the agro-ecological condition of swat valley.

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