Effect of tillage and phosphorus interaction on yield of mungbean (*Vigna radiata* L., Wilczek) with and without moisture stress condition

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ABSTRACT

The objective of this research was to evaluate the impact of phosphorus levels (P) and tillage depths (T) on yield components and yield of mungbean (*Vigna radiata* L., Wilczek) under irrigated (no moisture stress) and dryland (with moisture stress) conditions. Two field experiments were conducted: one under irrigated and second under dryland conditions at the Agronomy Research Farm of The University of Agriculture, Peshawar-Pakistan during summer 2012. The impact of tillage depths and phosphorus levels was investigated on yield components and grain yield of mungbean. Three tillage depths (45, 30 and 15 cm) were used as main plots factor, while four P levels (0, 30, 60 and 90 kg P ha^{-1}) as subplots factor under both irrigated and dryland conditions. The results revealed that higher P levels resulted in earlier physiological maturity, increased number of nodules plant^{-1}, pods plant^{-1}, thousand grains weight and harvest index under both irrigated and dryland conditions. The higher P levels improved yield and yield components of mungbean irrespective of tillage depths. Under irrigated condition the shallow tillage depth (15 cm) was found more beneficial in terms of yield and yield components, while the deep tillage depth (45 cm) performed better under dryland condition. We concluded from this study that application of 90 kg P ha^{-1} and shallow tillage (15 cm) was more beneficial for improving growth, yield and yield components of mungbean under irrigated condition. Under dryland condition, application of 90 kg P ha^{-1} and deep tillage (45 cm) was found better for improving growth, yield and yield components of mungbean.

Keywords: mungbean, dryland, irrigated, tillage depth, P level, moisture, yield, yield components, nodules, weeds

INTRODUCTION

Mungbean (*Vigna radiata* L., Wilczek) is one of the important summer grain legume crops in Pakistan. In Pakistan, mungbean was grown on an area of about 141, 000 ha with a total production of 93000 Mg (661 kg ha^{-1}). I. Khyber Pakhtunkhwa Province (Northwest Pakistan, semiarid climate), it was grown on an area of about 7.3, 000 ha with a total production of 4.4000 Mg with an average yield of about 603 kg ha^{-1} (MINFAL 2011-12). Limitation and irregular rainfall cause decreasing in crops yield in semiarid regions (Eack, 1996; Zhang and Outlaw, 2001; Amanullah et al., 2011). According to Postel (2000), drought problems for mungbean are worsening with the rapid expansion of water stressed areas of the world. Drought stress during crop growth season is a major problem that needs attention (Khodabandeh, 2005).

Many researchers also reported earlier that the P unavailability and low soil moisture are the major issues for decreasing field crops productivity in semiarid climates (Hilhorst et al., 2000; Rashid, 2001; Malik et al., 2002; Liu et al., 2003; Asaduzzaman et al., 2008; Amanullah et al., 2011; Zare et al., 2012). As P is the second most critical plant nutrient for crop production after nitrogen. Application of P under semiarid climates is found to improve crop growth, yield, yield components and crop quality (Ahmad et al., 1992; Malik et al., 2002; Amanullah et al., 2012; Amanullah et al., 2014), while its deficiency cause significant loss in crop productivity (Raj et al., 1999) and profitability (Amanullah et al., 2012). Phosphorus has favorable effects on leguminous crops (Brady, 1984) and also has positive effect on crop quality as increases protein content in mungbean (Sushil et al., 1997). The P deficient situation become worst in dryland condition where there is always shortage of moisture that affect fertilizer efficiency and successful crop production (Raj et al., 1999; Jan et al., 2012a). Fertilizer management is therefore considered one of the important factors for improving crop productivity (Asaduzzaman et al., 2008; Amanullah et al., 2014 and 2015).

Under semiarid climates, tillage management is considered the most effective farm activity which improves soil physical condition, root development, nutrient uptake and crop yield (Carter et al., 1982; Armstrong et al., 2003; Rosner et al., 2008; Demjanova et al., 2009; Amanullah et al., 2014, 2015a and 2015b). On the other hand, inappropriate tillage practices cause soil structure destruction, accelerated erosion, loss of organic matter and fertility, and disruption in cycles of water, organic carbon, and plant nutrient (Lal, 1993). Deep tillage practices under moisture stress condition, improve aeration (Zorita, 2000), soil porosity (Hao et al., 2001), conserve soil moisture and plant nutrients (Patil et al., 2006) and increase crop productivity (Amanullah et al., 2015). Crop P requirements and tillage depths may vary in soils having different moisture contents. There is lack of published research work on P and tillage management under irrigated and dryland conditions in semiarid climates. This research project was therefore designed with the objective to investigate impact of various tillage depths and P levels for improving growth and yield of mungbean grown under the irrigated and dryland conditions in the semiarid climates in Peshawar valley.

MATERIALS AND METHODS

Site description

Field experiments were conducted at the Agronomy Research Farm of The University of Agriculture Peshawar, during summer 2012 with the objective to investigate effects of tillage (T) depths (45, 30 and 15 cm) and phosphorus (P) levels (0, 30, 60 and 90 kg P ha^{-1}) on yield and yield components of mungbean (*Vigna radiata* L., Wilczek) grown under irrigated and dryland condition (W). The Agronomy Research Farm is located at 34.01 ◦N, 71.35 ◦E, at an altitude of 350 m above sea level in the Peshawar valley. Peshawar is located about 1600 km north of the Indian Ocean and has semiarid climate. The research farm is irrigated by the Warsak canal from the Kabul River. Soil texture is clay loam, low in organic matter (0.87%), extractable phosphorus (6.57 mg kg^{-1}), exchangeable potassium (121 mg kg^{-1}), and alkaline (pH 8.2) and is calcareous in nature (Amanullah et al., 2009). The climate of the area is semiarid where the mean annual rainfall is very low (300 to 500 mm), 60-70% rainfall occurs in summer, while the remaining 30-40% rainfall occurs in winter (Amanullah et al., 2010).

Experimentation

Two separate field experiments were conducted under irrigated and dryland condition. The experiment under each irrigated and dryland conditions (W) was laid out in split plot arrangements using three replications. Tillage depths (45, 30 and 15 cm) were used as main plots factor and P levels 0, 30, 60 and 90 kg P ha^{-1}) as subplots factor. Each replication consisted of 12 (3 depths x 4 P levels) treatments. A sub-plot size of 5 m by 4 m, having 10 rows, 4 m long and 50 cm apart was used. Tillage implements viz. chisel plough, mouldboard plough and cultivators were used for 45, 30 and 15 cm depths, respectively. Mungbean cultivar "NM-54" was used as test crop and sown at rate of 25 kg ha^{-1} on June 23, 2012. A uniform basal dose of 30 kg N ha^{-1} as urea (46 % N) was applied and mixed with the soil during seedbed preparation to all plots. Phosphorus in the form of single super phosphate (18 % P_2O_5) was applied at the time of sowing. All other agronomic practices were carried out equally during the growing season. The crop was harvested on 9th September, 2012**.**

Data recording and handling

Days to physiological maturity

Days to physiological maturity were counted from emergence till 50% pods changed its color to light brown.

Weeds dry weight

Weeds were harvested in 1 m^2 in each sub plot before first flowering. The material was sun dried and then dry weight was measured with the help of electronic balance and then converted into kg ha^{-1}.

Number of nodules plant^{-1}

Nodules per plant at the time of pod initiation were counted by uprooting five plants randomly in each subplot and then averaged.

Number of pods plant^{-1}

Number of pods plant^{-1} were counted in 10 randomly selected plants in each subplot and then averaged.

Number of seeds pod^{-1}

Number of seeds pod^{-1} were calculated on randomly selected 10 pods for each subplot and then average was worked out.

1000 grains weight

Grains weight of randomly 1000 seeds was taken from seed lot of each subplot and was weighed with the help of electronic balance.

Biomass yield

Data on biomass yield was recorded by harvesting the four central rows in each subplot. The material was sundried up to constant weight, weighed and then converted into kg ha^{-1} with the help of following formula:

$$\text{Biological yield (kg ha}^{-1}\text{)} = \frac{\text{Weight of plant materials in four rows (kg)}}{\text{No of rows x Row length x R-R distance}} \times 10{,}000 \text{ m}^2$$

Grain yield

The four harvested central rows of each treatment after drying were threshed; the seeds were cleaned, weighed and then converted into kg ha^{-1} with the help of following formula:

$$\text{Grain yield (kg ha}^{-1}\text{)} = \frac{\text{Grain weight of four rows (kg)}}{\text{No of rows x Row length x R-R distance}} \times 10{,}000 \text{ m}^2$$

Harvest index

Harvest index was calculated by using the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

Statistical analysis

The collected data on various parameters were subjected to the analysis of variance according to split plot design (Steel *et al.*, 1996) and means between treatments were compared using least significance difference (LSD) test at 5% level of probability ($P \leq 0.05$). The data was analyzed with MSTAT Statistical Software (Michigan State University, USA). For significant phosphorus into tillage interactions bar graphs were made and error bars with standard deviation were applied.

RESULTS

Response of mungbean under irrigated condition

Impact of tillage depths

Tillage depths had significant ($P\leq0.05$) impact only on weeds dry weight (WDW), number of nodules per plant (NPP), number of pods per plant (PPP), number of seeds per pod (SPP), 1000-grains weight (TGW), biomass yield and grain yield of mungbean grown under irrigated condition (Table 1). Deep tillage (45 cm) had significantly produced less WDW (24 kg ha^{-1}) and resulted in lower PPP (27), TGW (50.48 g) and grain yield (742 kg ha^{-1}). Reduced tillage (15 cm) had resulted in highest PPP (32), SPP (9), TGW (53.52) and grain yield (810 kg ha^{-1}). The biomass yield of mungbean under irrigated condition was increased to maximum (2705 kg ha^{-1}) at 30 cm depth. Tillage depths had showed no significant effect on physiological maturity and harvest index under irrigated condition (Table 1).

Impact of phosphorus levels

Phosphorus levels had significant ($P\leq0.05$) impact on all the parameters of mungbean under irrigated condition (Table 1). Physiological maturity enhanced (early), yield and yield components increased in mungbean while increasing P level. Application of 60 and 90 kg P ha^{-1} had statistically similar days to PM (68 days each) and number of NPP (14 and 13), respectively. The control plots (P not applied) had delayed PM (71 days) and produced less number of NPP (7). The highest WDW (34 kg ha^{-1}), number of PPP (34), number of SPP (10), TGW (56.91 g), biomass yield (2933 kg ha^{-1}), grain yield (908 kg ha^{-1}) and harvest index (31.0 %) was obtained with the application of the highest P level (90 kg P ha^{-1}).

The control plots (0 kg P ha^{-1}) had produced minimum WDW (21 kg ha^{-1}), number of PPP (22), number of SPP (7), TGW (46.23 g), biomass yield (2258 kg ha^{-1}), grain yield (613 kg ha^{-1}) and harvest index (27.1 %).

Phosphorus and tillage interaction

Interaction between P levels and tillage depths had significant ($P \leq 0.05$) effects on WDW, PPP, SPP, TGW and grain yield under irrigated condition (Table 1). The WDW increased with increase in P level under each tillage depths, however, the WDW increased with increase in tillage depths (Fig. 1). Increase in number of PPP was observed with the increase in P levels under different tillage depths (Fig. 2). Interestingly, the increase in tillage depths decreased the number of PPP of mungbean under irrigated condition (Fig. 2). Increase in number of SPP was observed with the increase in P levels under different tillage depths (Fig. 3), and the increase was more under shallow tillage (15 cm). Increase in TGW was observed with the increase in P levels under different tillage depths, and the combination of 90 kg P ha^{-1} + 15 cm tillage depth resulted in significantly heaviest grains in mungbean grown under irrigated condition (Fig. 4). Grain yield increased with the increase in P levels under different tillage depths. Under shallow tillage system (15 cm depth), application of 60 and 90 kg P ha^{-1} had produced statistically similar grain yield (Fig. 5).

Response of mungbean under dryland condition

Impact of tillage depths

Tillage depths had significant ($P \leq 0.05$) effect only on number of PPP, TGW, biomass and grain yields of mungbean grown under dryland condition (Table 2). Deep tillage (45 cm) had produced highest number of PPP (27), heaviest TGW (48.22 g), highest biomass yield (2357 kg ha^{-1}) and grain yield (664 kg ha^{-1}). Reduced tillage (15 cm) had resulted in lowest number of PPP (24), biomass yield (2235 kg ha^{-1}) and grain yield (555 kg ha^{-1}). Tillage depths had showed no significant effect on days to PM, WDW, number of NPP, number of SPP and harvest index under dryland condition (Table 2).

Impact of phosphorus levels

Phosphorus levels had significant (P≤0.05) impact on all the parameters of mungbean under dryland condition (Table 2). Physiological maturity enhanced (early), yield and yield components increased in mungbean while increasing P level. Application of 60 and 90 kg P ha^{-1} had statistically similar days to PM (66 days each), harvest index (27.9 % each 13) and number of NPP (9 and 8, respectively) under dryland condition. The lowest WDW (12 kg ha^{-1}), and the highest number of PPP (33), number of SPP (9), TGW (50.60 g), biomass yield (2717 kg ha^{-1}) and grain yield (758 kg ha^{-1}) was obtained with the application of the highest P level (90 kg P ha^{-1}). The control plots (P not applied) had delayed PM (69 days), produced less number of NPP (5), number of PPP (16), number of SPP (6), TGW (44.59 g), biomass yield (1864 kg ha^{-1}), grain yield (452 kg ha^{-1}) and harvest index (27.3 %) under dryland condition (Table 2).

Phosphorus and tillage interaction

Interaction between P levels and tillage depths had significant (P≤0.05) effects on biomass and grain yields of dryland mungbean (Table 2). Both biomass (Fig.6) and grain yields (Fig. 7) increased with the increase in P levels under different tillage depths and the increase was more with increase in tillage depth.

DISCUSSION

Deep tillage (45 cm) had relatively (P ≥ 0.05) delayed physiological maturity under both irrigated (Table 1) and dryland (Table 2) mungbean. The delay in days to physiological maturity with deep tillage system probably may be due to the delay in the days to flowering and pods formation (Amanullah et al., 2014). Amanullah et al. (2014) suggested that the deep tillage system might have increased water storage and availability of more nitrogen available to the plants under deep tillage system that delayed the phenological development in mungbean. Variation in soil water contents among different tillage practices was reported by Alam et al. (2014). Weeds biomass decreased under deep tillage system than shallow tillage under irrigated (P ≤ 0.05) and dryland (P ≥ 0.05) mungbean (Table 1 and 2, respectively). Likewise our results, Demjanova et al. (2009) and Ozpinar (2006) reported less weed dry biomass with mouldboard plowing as compared to reduced tillage practices. Gruber and Claupein (2009) reported that mouldboard plowing resulted in lowest weed infestation and the highest weed infestation occurred in chisel plow treatment. Under deep tillage system number of NPP increased, while number of NPP was reduced under shallow tillage system. The better results of deep tillage on number of NPP probably may be due to soil softness, penetration of deeper roots in the soil, and conservation of soil moisture. According to Van Kessel and Hartley (2000) reported that increased soil moisture increases the potential of biological nitrogen fixation in legume crops. Jan et al. (2012b) noticed greater number of nodules plant^{-1} in chickpea under conventional tillage system. According to Akhtar et al. (2005), deep tillage resulted in better conservation of soil moisture, which ultimately was used more efficiently by the groundnut crop for longer periods as compared with shallow tillage. The yield and yield components increased with decreased in tillage depth in mungbean grown under irrigated condition (Table 1). In contrast, the yield and yield components decreased with decreased in tillage depth in mungbean grown under dryland condition (Table 2). According to Amanullah et al. (2014), under irrigated condition, the increase in tillage depth reduced plant height, number of leaves plant^{-1} and straw yield. They reported taller plants, more number of leaves plant^{-1} and highest straw yield under deep tillage (45 cm) in mungbean grown under dryland condition. Proper tillage management under semiarid condition conserves soil fertility and moisture thereby increases crop yield (Carter *et al*., 1982; Demjanova et al. (2009). Jan et al. (2012) obtained maximum grain yield of mungbean (663 kg ha^{-1}) under conventional tillage system and minimum grain yield (527 kg ha^{-1}) was recorded under reduced tillage system. Akhtar et al. (2005) reported that maximum net return was obtained when soil was tilled with mouldboard plough (Rs. 6652), followed by chisel plough (Rs. 4927) and least by disc plough (Rs. 2227) over cultivator. Singh et al. (2007) found that deep tillage system produced a higher grain yield than conventional sowing method. Khan *et al.* (2011) reported that mouldboard plowing produced better results than cultivator. In contrast to our results, Salahin et al. (2011) reported that tillage had no significant effect on biomass and straw yield of mungbean. Omondi et al. (2014) also reported that grain yield between tillage methods and among different varieties of soybean were not significant in different sites.

The increase in P levels resulted in earlier PM in mungbean under both irrigated and dryland conditions. Amanullah et al. (2014) reported that mungbean applied with no P (P-control) had delayed flowering and pods formation. Early flowering and pods formation was observed with the application of the highest rate of 90 kg P ha^{-1} (Amanullah et al., 2014). These results are in close confirmation with those of Sison and Margale (1981) who reported that P application resulted in the early maturity in cowpea (V. unguiculata L.). Jan et al. (2012) observed delayed maturity (64 days) in the P-control plots while early maturity (59 days) was observed in plots where 40 or 60 kg P_2O_5 ha^{-1} was applied indicating that P application had earlier maturity in mungbean. Weeds biomass increased with increase in P level under irrigated condition and decreased with increase in P level under dryland condition. According to Naeem et al. (2000), yield reduction in mungbean, as a result of weed competition, was more sever in unfertilized plots indicating that under poor nutrition, the competitive ability of weeds was higher and more pronounced. They reported that weed interference was reduced considerably at 50 kg P_2O_5 ha^{-1}. Higher level of phosphorus (75 kg P_2O_5 ha^{-1}) could not improve competitive ability of mungbean further to be significant than conventional level. Aghaie et al. (2013) suggested that P fertilization increased competition ability of maize crop with velvetleaf weeds; which might be due to increasing effect of P on maize height that could suppress velvetleaf. As weeds have a large nutrient requirement and will absorb as much or more than crops (Bonifas and Lindquist, 2006). It seems logical that more fertilizer should reduce nutrient competition (Zimdhal, 2007). Cralle et al. (2003) indicated that use of the recommended P nutrition from soil testing may be a key component to increase crop competition ability with weeds. Although crop competitiveness may improve with improved nutrient status, some weeds are more effective at utilizing excess resources than are crops. Competition between crops and weeds for nutrients, and for other factors (light, space, water) at different nutrient levels, are complex interactions that depend on many factors (Frick and Johnson, 2015). The increase in number of number of NPP with application of P over control probably may be due to the increase in the root lengths, number and weight of mungbean with P application. Brady (1984) reported favorable effects of P application on the number and weight of effective nodules on the root system of leguminous crops. Hussain et al. (2014) reported a maximum of 8.67 nodules $plant^{-1}$ in mungbean which received P along with *Rhizobium* inoculation under semiarid condition. Gowda and Gowda (1978) reported that mungbean requires P to increase N fixation and to improve the yield and quality of grain. Hussain et al. (2014) reported that application of P increased N uptake in mungbean. Amanullah and Stewart (2013) found significant increase in the root biomass of oat with application of P over control. Costa *et al*. (2002) reported that the mineral nutrients P and N exerted pronounced influences on assimilate production and dry matter partitioning into roots. Hence, P influence root development (Hossain and Hamid, 2007) and therefore may have increased the number of NPP in mungbean. Increase in yield and yield components of mungbean with increase in P levels (90 > 60 > 30 > 0 kg P ha^{-1}) probably may be due to the availability of an optimum amount of P from the soil had positive impact on the growth (Malik et al., 2002; Amanullah et al., 2014) and thereby produced more yield components, yields and harvest index in mungbean. These results are in line with those of Malik et al. (2002) who reported that application of P at the rate of 50-75 kg ha^{-1} to mungbean crop significantly increased the number of pods $plant^{-1}$, seeds pod^{-1}, TGW and grain yield. On the other hand, higher yields of mungbean were obtained by Lange et al. (2007) with application of 90 kg P ha^{-1} and Ali et al. (2010) with application of 84 kg P ha^{-1}. In our current study the increase P level also had positive impact on the harvest index of mungbean. These results are in also line with the findings of Ahmad et al. (1992) who reported an increase in the harvest index in mungbean in response to P application. According to Jan et al. (2012) the increase in yield and yield components of mungbean with application of P was attributed to the increase in emergence of 29 plants m^{-2} as compared to less number of 26 plants m^{-2} under P-control plots that resulted in low yield. The higher grain yield with application of P probably may be due to better root development and greater translocation of photosynthates towards the sink development and higher yield components (Malik et al., 2003; Jain et al., 2007; Singh and Ahlawat, 2007; Pal et al., 2014; Hussain et al., 2014) in mungbean. The application of P to mungbean has been reported to increase dry matter at harvest, number of pods per plant, seed per pod, 1000 grain weight, seed yield and total biomass (Mitra et al., 1999). The increase in yield and yield components with application of higher P levels had showed positive relationship with harvest index in maize (Amanullah et al., 2010). The improvement of mungbean growth, yield and yield components with P application over P-control probably may be due to several key functions of P, including energy transfer, photosynthesis, transformation of sugars and starches, nutrient movement within the plant and transfer of genetic characteristics from one generation to the next (https://www.ipni.net).

The delayed days physiological maturity (PM) of mungbean grown under irrigated condition probably may be due to the availability of water and so uptake of nutrients especially nitrogen which is considered to delay the phenological developments in crop plants (Amanullah et al., 2009). The results published earlier by Amanullah et al. (2014) from the same study confirmed that mungbean grown under irrigated condition had delayed their flowering (48 days) and pods formation (57 days). On the other hand, mungbean grown under dryland condition had produced early flowering (46 days) and pods formation (55 days) as compared with irrigated condition (Amanullah et al., 2014). This indicates that delay in days to flowering and days to pod formation in mungbean also delayed the days to PM. Likewise, Thomas et al. (2004) reported that mungbean plants under water stress (dryland) condition attained maturity earlier than the well-watered treatment. Water stress at the reproductive stage severely affects grain yield of mungbean more than at other stages. In addition, the time of flowering and maturity was shortened under stress compared to well-watered conditions (Sadeghipour, 2009). The early completion of phenological development is better for mungbean under dryland condition. However, early phenological development it is not economical under dryland condition due to poor pod setting in mungbean (Liu et al., 2003; Ranawake et al., 2011). The increase in weeds biomass under irrigated condition probably may be due to the availability of soil moisture and nutrients that enabled more weeds seeds to germinate and probably with better growth. In contrast, the decrease in weeds biomass under dryland condition probably may be due to the unavailability or less availability of soil moisture/nutrients that reduced weeds emergence, growth and biomass. According to Ihteramullah et al. (2013), weeds population significantly reduced under dryland wheat crop. Like field crops, weeds also need proper soil and environmental condition for their growth, therefore proper water and nutrients supply under irrigated condition increased weeds biomass than dryland condition. In the current study number of nodules plant^{-1} was less in mungbean grown under dryland condition than irrigated condition. These results support the findings of Hungria and Vargas (2000) and Ramos et al. (2003), they reported that N fixations and nodules reduced under water stress (dryland) condition. The decrease in number of NPP under dryland condition probably may be due to less root dry weight formation under drought stress (Ashraf and Iram, 2005; Abbas and Mohamed, 2011).

Improvement in yield and yield components of mungbean under irrigated condition probably may be due to the availability of optimum amount of water and nutrients which had positive impact on cell division and enlargement with better growth and thereby increased yield and yield components of mungbean. Drought stressed plants diverted significantly higher dry matter to roots and stems, while well-watered plants diverted to pods and grains (Kumar and Sharma, 2009). According to Kramer and Boyer (1997), yield of mungbean is more dependent on an adequate supply of water than on any other single environmental factor. Prasad et al. (1989) found higher straw and grain yields of mungbean with three irrigations as compared to one or no irrigation. Likewise, Shihab et al. (2013) reported improvement in growth and yield of mungbean with application of irrigation as compared with no irrigation. Decline in the yield and yield components of mungbean under dryland condition probably may be due to the unavailability or less availability of the required amount of water and nutrients that had probably shortened the phenological development and growth of mungbean (Amanullah et al., 2014) and thereby decreased yield and yield components. These results are also in agreement with those of Zare et al. (2012) and Asaduzzaman et al. (2008) who reported stunted growth, less yield and yield components of mungbean under water stress condition. Zare et al. (2012) reported 22.69% yield loss under water stress (dryland) condition as compared with non-stress (irrigated) condition. According to Liu et al. (2003), the yield loss caused by drought stress condition in mungbean was mainly due to an increased rate of floral and pod abortion. Water stress also affects crop phenology, leaf area development, number of leaves per plant (Ranawake et al., 2011) that finally results in low yield (Abdel et al., 2011). Interestingly, the HI of both irrigated and dryland mung was statistically the same. According to Bourgault et al. (2007), deficit irrigation influence HI of common bean and mung bean. Common bean seems to decrease its HI with increasing irrigation stress, while mungbean seems to increase HI with increasing irrigation stress. Drought stress reduces the biomass and despite slightly increasing the harvest index, it reduces production per unit area and this significantly decreases the number of pods, pod lengths, number of seeds per pod, seed length & diameter, and weight of 100 grains and ultimately reduces the seed yield (Taiz and Zeiger, 2002). The increase in yield and yield components of mungbean under irrigated condition over dryland condition probably may be due to the physiological functions of water viz. serves as a medium for biochemical reactions in cells, activations of enzymes, cell enlargement, transport of solutes between organs, and cooling of leaves during transpiration (http://www.uoguelph.ca). The higher P levels resulted in earlier PM, increased number of NPP, PPP, SPP, TGW, GY and

HI under different tillage depths. Marral et al. (2014) reported maximum gross (1945 USD ha^{-1}) and net income (1568 USD ha^{-1}) were obtained by employing the conventional tillage + 90 kg P ha^{-1}, while minimum gross income (979 USD ha^{-1}) and net income (687 USD ha^{-1}) were obtained where zero tillage + 30 kg P ha^{-1} was used.

CONCLUSION

Increase in P level improved growth, yield and yield components of mungbean grown under both irrigated and dryland conditions (90 > 60 > 30 > 0 kg P ha^{-1}). Shallow tillage (15 cm depth) was found more beneficial for mungbean under irrigated condition. Dryland mungbean grown had better growth, higher yield and yield components under deep tillage system (45 cm). We suggest that high yielding and stress resistant mungbean varieties need to be developed and evaluated under different agro-ecological zones.

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Table 1. **Response of days to physiological maturity (PM), weeds dry weight (WDW), number of nodules plant^{-1} (NPP), number of pods plant^{-1} (PPP), number of seeds pod^{-1} (SPP), thousand grains weight (TGW), biomass yield (BY), grain yield (GY) and harvest index (HI) of irrigated mungbean (*Vigna radiata* L., Wilczek) as affected by tillage depths, phosphorus levels and interaction.**

Tillage Depths (cm)	PM (days)	WDW (kg ha^{-1})	NPP (number)	PPP (number)	SPP (number)	TGW (g)	BY (kg ha^{-1})	GY (kg ha^{-1})	HI (%)
45	70	24	12	27	8	50.48	2568	742	28.8
30	69	29	12	28	8	50.97	2705	768	28.3
15	69	28	10	32	9	53.22	2477	810	29.8
Significance	ns	*	*	*	*	*	*	*	ns
Phosphorus levels (kg ha^{-1})	**PM (days)**	**WDW (kg ha^{-1})**	**NPP (number)**	**PPP (number)**	**SPP (number)**	**TGW (g)**	**BY (kg ha^{-1})**	**GY (kg ha^{-1})**	**HI (%)**
0	71	21	7	22	7	46.23	2258	613	27.1
30	70	24	11	28	8	49.87	2377	738	27.4
60	68	29	14	31	9	53.21	2766	835	30.2
90	68	34	13	34	10	56.91	2933	908	31.0
Significance	*	*	*	*	*	*	*	*	*
Interaction	ns	*(Fig.1)	ns	*(Fig.2)	*(Fig.3)	*(Fig.4)	ns	*(Fig.5)	ns

^{ns} stands for non-significant and * stands for significant data in the same category at $p \leq 0.05$

Table 2 **Response of days to physiological maturity (PM), weeds dry weight (WDW), number of nodules plant^{-1} (NPP), number of pods plant^{-1} (PPP), number of seeds pod^{-1} (SPP), thousand grains weight (TGW), biomass yield (BY), grain yield (GY) and harvest index (HI) of dryland mungbean (*Vigna radiata* L., Wilczek) as affected by tillage depths, phosphorus levels and interaction.**

Tillage Depths (cm)	PM (days)	WDW (kg ha^{-1})	NPP (number)	PPP (number)	SPP (number)	TGW (g)	BY (kg ha^{-1})	GY (kg ha^{-1})	HI (%)
45	68	15	7	27	8	48.22	2357	664	28.1
30	67	16	7	25	7	46.99	2304	601	27.9
15	67	18	6	24	7	48.04	2235	555	26.9
Significance	ns	ns	ns	*	ns	*	*	*	ns
Phosphorus levels (kg ha^{-1})	**PM (days)**	**WDW (kg ha^{-1})**	**NPP (number)**	**PPP (number)**	**SPP (number)**	**TGW (g)**	**BY (kg ha^{-1})**	**GY (kg ha^{-1})**	**HI (%)**
0	69	15	5	16	6	44.59	1864	452	27.3
30	68	16	6	24	7	46.94	2132	524	27.4
60	66	19	9	29	8	48.86	2480	692	27.9
90	66	12	8	33	9	50.60	2717	758	27.9
Significance	*	*	*	*	*	*	*	*	*
Interaction	ns	ns	ns	ns	ns	ns	*(Fig.6)	*(Fig.7)	ns

^{ns} stands for non-significant and * stands for significant data in the same category at $p \leq 0.05$

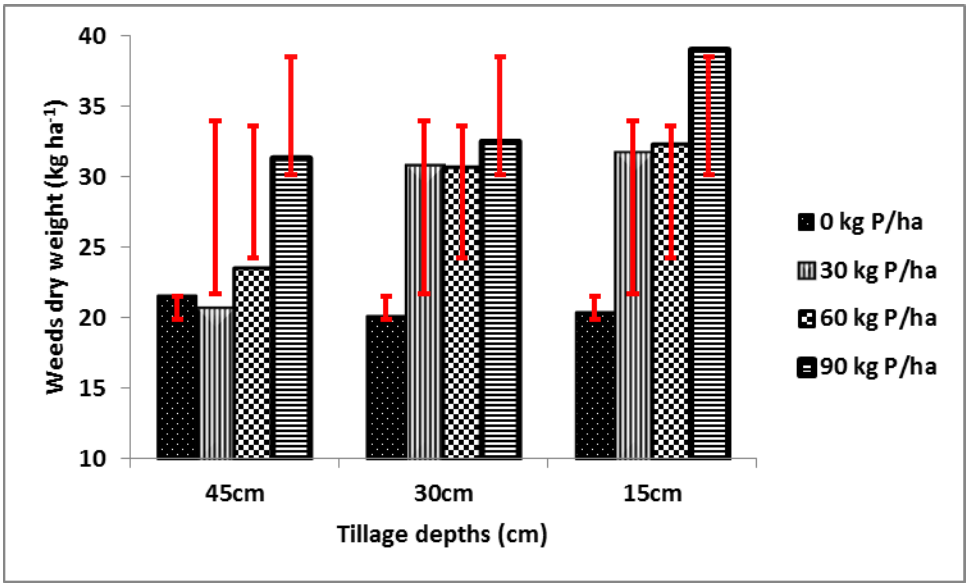

Fig. 1. Weeds dry weight (kg ha^{-1}) of mungbean (*Vigna radiata* L., Wilczek) as affected by interaction between tillage depths and phosphorus under irrigated condition.

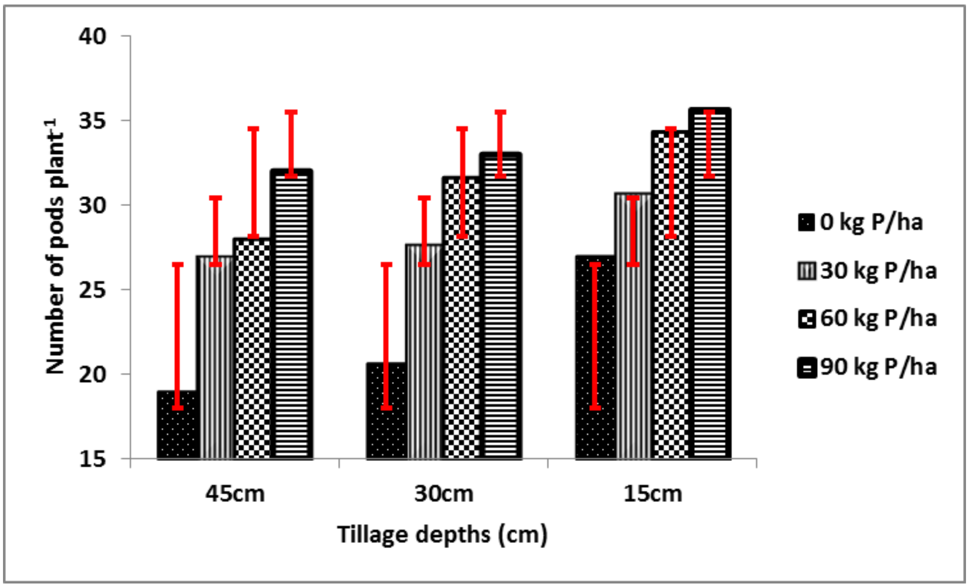

Fig. 2. Number of pods plant^{-1} of mungbean (*Vigna radiata* L., Wilczek) as affected by interaction between tillage depths and phosphorus under irrigated condition.

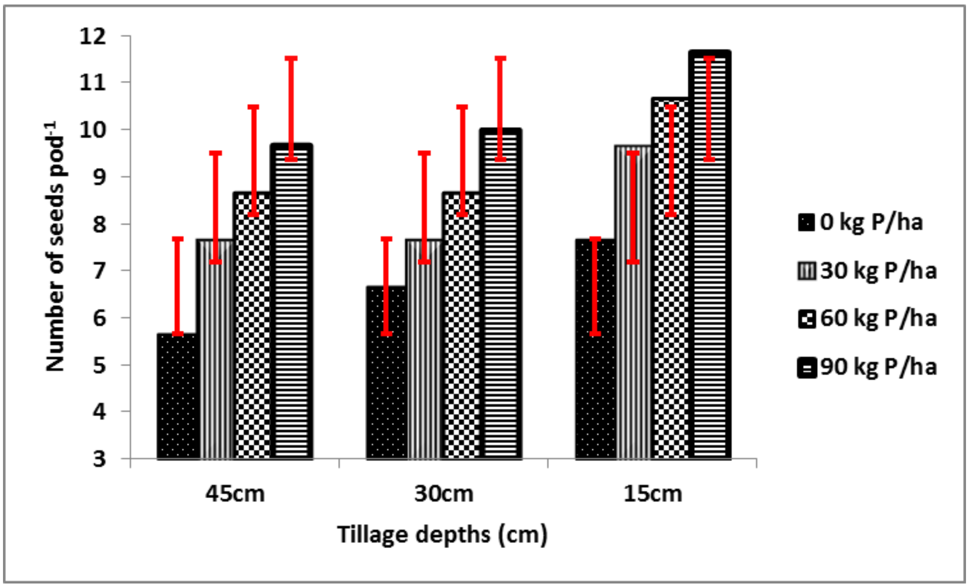

Fig. 3. Number of seeds pod^{-1} of mungbean (*Vigna radiata* L., Wilczek) as affected by interaction between tillage depths and phosphorus under irrigated condition.

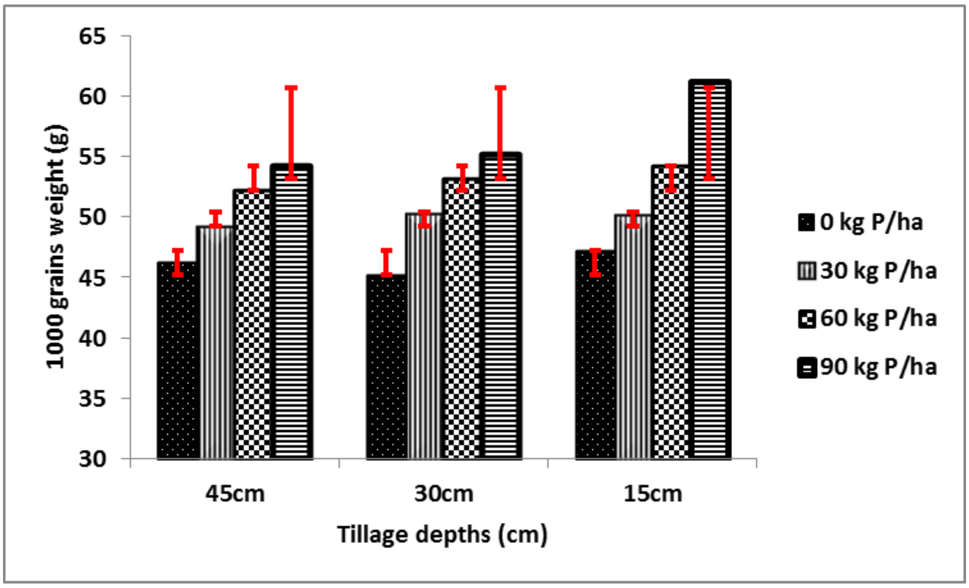

Fig. 4. Thousand grains weight (g) of mungbean (*Vigna radiata* L., Wilczek) as affected by interaction between tillage depths and phosphorus under irrigated condition.

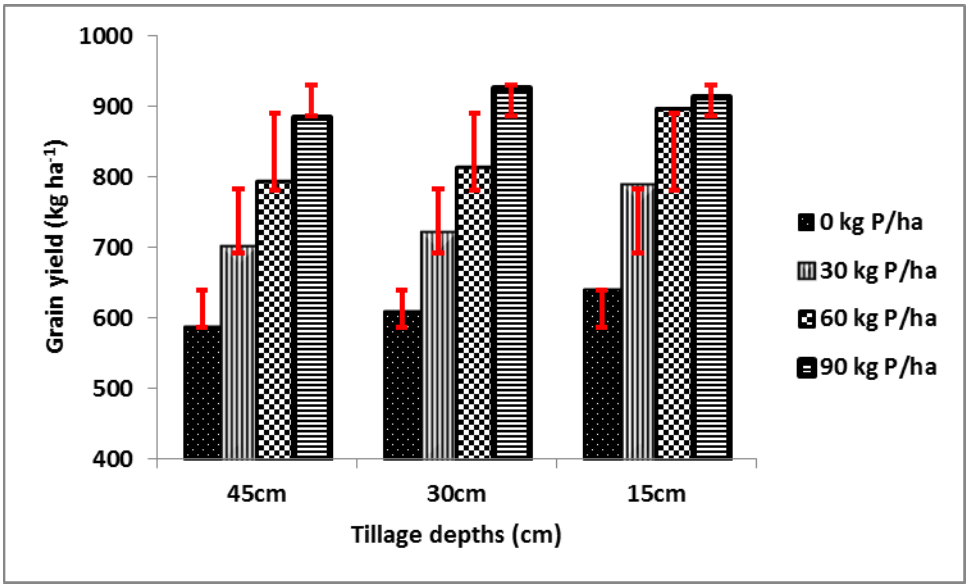

Fig. 5. Grain yield (kg ha^{-1}) of mungbean (*Vigna radiata* L., Wilczek) as affected by interaction between tillage depths and phosphorus under irrigated condition.

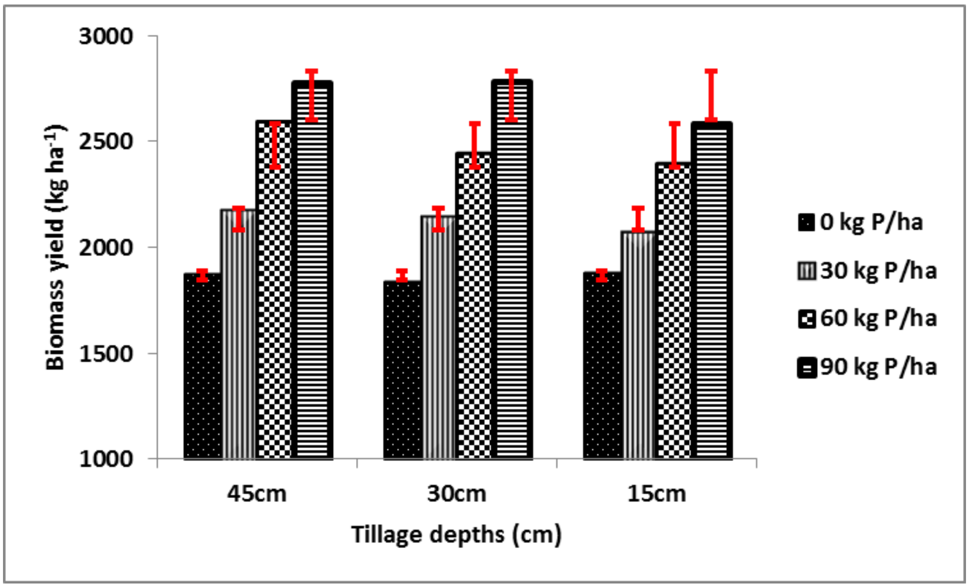

Fig. 6. Biomass yield (kg ha^{-1}) of mungbean (*Vigna radiata* L., Wilczek) as affected by interaction between tillage depths and phosphorus under dryland condition.

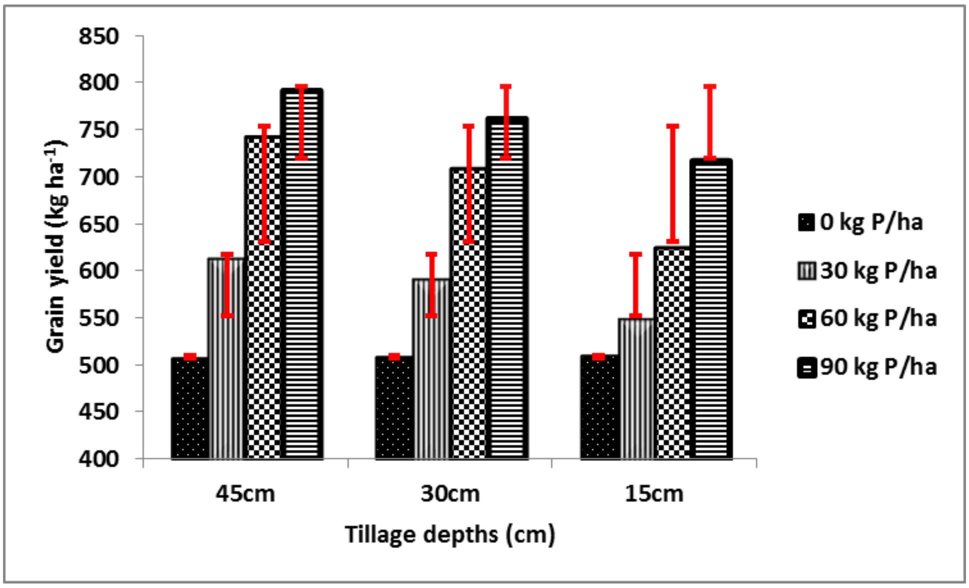

Fig. 7. Grain yield (kg ha^{-1}) of mungbean (*Vigna radiata* L., Wilczek) as affected by interaction between tillage depths and phosphorus under dryland condition.