Research Article

Impact of tillage systems on growth and yield of Mungbean (*Vigna radiata* L., Wilczek) varieties under dryland condition

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Abstract

The objective of this experiment was to study the impact of different tillage systems (zero, conventional, maximum and minimum) on growth and yield performance of four mungbean varieties (NM-92, NM-93, NF9M12-12 and Local) under dryland condition. The experiment was laid out in randomized complete block design with split plot arrangement having four replications. Tillage systems were allotted to the main plots and varieties to subplots. The results revealed that higher emergence m^{-2} (19 seedling m^{-2}), delayed emergence (6 days), higher number of branches (5 branches plant^{-1}) and number of pods plant^{-1} (20), taller plants (54 cm), heavier 1000-grains (26.08 g) and highest grain yield (384 kg ha^{-1}) was recorded for variety NM-92. Increase in number of tillage had resulted in significantly higher number of seedlings m^{-2} (24), early emergence (6 days), minimum number of branches plant^{-1} (4), taller plants (66 cm), higher number of pods plant^{-1} (23), higher biological (2023 kg ha^{-1}) and grain yield (402 kg ha^{-1}). It was concluded from this study that growing mung variety “NM-92” under maximum tillage system showed promising results in terms of higher yield and yield components under dryland condition.

Key words: Mungbean; growth; yield; varieties; tillage systems; dryland.

Introduction

Mungbean (*Vigna radiata* L., Wilczek), a member of the family leguminosae grown mainly on dry land, is an important kharif season (summer) crop of Pakistan [1]. Malnutrition is one of the major problems in the whole Khyber Pakhtunkhwa (KP)

province of Pakistan in general and in the northern parts of KP in particular is mainly due to the protein deficiency in the diet. Food legumes have an important role to play not only in increasing the quantity of food but in improving the quality of their cereal based diets [2]. Among pulses mungbean is

an important crop cultivated in many Asian countries as well as in Pakistan. In Pakistan, mungbean was grown on an area of about 141 thousand hectares with a total production of 93 thousand tons and average yield 661 kg ha^{-1} . While in the KP province of Pakistan mungbean was grown on an area of about 7.3 thousand hectares with a total production of 4.4 thousand tones with an average yield of about 603 kg ha^{-1} [3].

Mungbean can play a major role in the national economy of Pakistan, if given place in cropping pattern. There is a great need to improve the production of pulses in the country, using all possible resources. The yield and quality of mungbean can be improved by applying best agronomic practices such as optimum tillage practices and selection of suitable high yielding variety. Optimum tillage practice play an important role in contributing to the high yield because in case of less tillage operation, most of soil is hard, root cannot penetrate deep into the soil. Tillage is a physical operation of soil, which aims to destroy weeds in the incorporate crop residues and amendments into soil, increase infiltration and reduce evaporation, prepare seedbed and break hard layers to assist root penetration [4]. There are different kinds of tillage operations such as no tillage, reduced tillage, deep tillage etc. [5]. Recently, the reduced tillage technique has been gaining popularity [6]. Like several other factors, proper land preparation with different tillage practices plays an important role in improving the production of drylands by moisture conservation. Soil moisture is the life blood for plant growth contributing 80-90 percent to herbaceous plants and transport medium for nutrients from soil to plants [7]. Adoption of conservation tillage practices, which include no tillage and several forms of reduced minimum tillage, is a means to increase soil organic matter (SOM), mitigate CO_2 emissions, and partly

address the rising environmental problems associated with modern agricultural practices [8].

The yield and quality of mungbean can be enhanced by applying best agronomic practices and use of high yielding cultivars. Cultivars of mungbean vary in yield and yield components [9-11]. Mung bean yield is very low as in Pakistan compared to other developed countries. The poor crop establishment is often cited as a major limitation for mungbean production [12, 13]. In the arid and semi-arid regions, water deficit is the main factor that limits crops performance [14]. The present study was therefore initiated with an objective to find out the high yielding variety and the best tillage system for improving growth and maximizing yield of mungbean under the dryland conditions of Karak, Khyber Pakhtunkhwa.

Materials and Methods

In order to study the performance of mungbean varieties under different tillage system in dryland (moisture stress) condition, an experiment was carried out at the Agricultural Research Station Ahmadwala, Karak during summer 2006. The experiment was laid out in randomized complete block design with split plot arrangement using four replications. The subplot size of $3 \text{ m} \times 1.5 \text{ m}$ was used. Each plot was consisted of five rows; three meter long with row to row distance of 30 cm. Sowing was done in July 2006. A uniform basal dose of N (20 kg ha^{-1}) and P_2O_5 (60 kg ha^{-1}) was applied during seed bed preparation as urea and single super phosphate, respectively. The four tillage systems “ZT = Zero tillage, CT = Conventional tillage, MinT = Minimum tillage, and MaxT = Maximum tillage” were allotted to main plots and the four varieties “Karak Local, NM-92, NM-93 and NF9M12-12” allotted to subplots. Zero tillage consisted of just one pass of a plow

prior to sowing, CT consisted of plowing twice before sowing, MinT consisted of plowing four times before sowing, while MaxT consisted of plowing eight times before sowing.

Data were recorded on emergence m^{-2} , days to emergence, plant height, number of branches and pods plant^{-1} , grains pod^{-1} , 1000 grains weight, grain and biological yields. Number of plants emerged m^{-2} was calculated from the counts of the seedling emerged in three representative rows of one meter length in each subplot and then it was converted into emergence m^{-2} . Days to emergence was recorded from the date of sowing to the date when 50% seedlings had emerged and then average was worked out. For recording number of branches plant^{-1} in each subplot, five plants were randomly selected for branches counting and then average was worked out. Plant height was recorded at the time of maturity by measuring the height of five randomly selected plants in each subplot from the base of the plant to the tip of the plant. Number of pods plant^{-1} were recorded in random sample of five plants from each three central rows and then average was worked out. Number of grains pod^{-1} were recorded by selecting ten pods from each subplot. These pods were threshed; number of grains pods^{-1} were counted and then averaged was worked out. For biological yield three central rows of three meter length were harvested. The whole material was sundried, weighed and then biological yield ha^{-1} was worked out. To record 1000 grains weight, from each subplot a random sample of thousand grains was counted and then weighed by electronic balance to record 1000 grains weight. The dried material of the three central rows in each subplots was threshed by beating with sticks, seed were cleaned, weighed and were converted into kg ha^{-1} .

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) according to the methods described by [15], and treatment means were compared using the least significant difference (LSD) at $P \leq 0.05$.

Results

Emergence m^{-2}

Tillage systems had a significant effect on emergence m^{-2} (Table 1); however, differences in varieties were not significantly different from each other. Interaction between varieties and tillage system had no significant impact emergence m^{-2} of mung bean under dryland condition. Higher emergence of 24 seedlings m^{-2} were observed in the plots where higher number of tillage was used, while less number of 12 seedlings m^{-2} were found in zero tilled plots. Higher emergence of 19 seedling m^{-2} were observed in plots sown with variety NM-92 while less number of 17 seedlings m^{-2} were observed in plots of Local variety, although these differences were statistically non-significant..

Days to emergence

Data recorded on emergence as affected by different tillage systems and varieties of mungbean is shown in Table 1. Statistical analysis of the data reveal that differences in days to emergence were non-significant for different varieties, tillage system and interaction between varieties and tillage system.

Number of branches plant^{-1}

Number of branches plant^{-1} were non-significant for different varieties, tillage systems and interaction (Table 1). However, higher number of 5 branches plant^{-1} were found in plots of both varieties NM-93 and NM-92, while less number of 4 branches each plant^{-1} in plots of varieties Local and NF9M12-12.

Plant height

Plant height data are presented in Table 1. Statistical analysis of the data showed that

tillage had a significant effect on plant height. Differences in varieties and interaction were non-significant. Taller plants of 66 cm heights were observed in plots where more number of tillage was used while dwarf plants of 42 cm were found in zero tilled plots. Taller plants of 54 cm heights were observed in plots sown with variety NM-93, while shorter plants of 52 cm were found in plots of local varieties although these differences were statistically non-significant.

Number of pods plant⁻¹

Tillage systems had a significant effect on number of pods plant⁻¹ (Table 1). Differences in mean values varieties, and interaction were non-significant. Higher number of 23 pod plant⁻¹ were observed in plots where maximum tillage system was used while less number of 15 pod plant⁻¹ were found in zero tilled plots. Similarly higher number of 23 pod plant⁻¹ were observed in plots of variety NM-92 while less number of 15 pods plant⁻¹ were observed of Local variety, although these differences were statistically non-significant.

Number of grains pod⁻¹

Number of grains pod⁻¹ showed non-significant response to varieties, tillage system and interaction (Table 2). However, higher number of 10 grain pod⁻¹ were observed in plots where both maximum and minimum tillage were used while less number of 9 grains pod⁻¹ were observed in zero and conventional tilled plot. Higher number of 10 grains pod⁻¹ were found in plots of varieties NM-92 and NM-93, followed by varieties NF9M12-12 and NM-93 each with 9 grains pod⁻¹.

Biological yield

Tillage system had significant effect on biological yield (Table 2). Differences in mean values of varieties were also significant. Highest biological yield of 1913 kg ha⁻¹ was observed in plots where more tillage were used while lowest biological

yield of 1833 kg ha⁻¹ was observed in zero tilled pots. Similarly higher biological yield of 1939 kg ha⁻¹ was recorded in plots of variety NM-93, followed by 1905 kg ha⁻¹ in plots Local variety.

1000-grains weight and grain yield

Statistical analysis of data revealed that tillage had a significant effect on 1000 grains weight, while varieties also showed significant variation in 1000 grains weight (Table 2). Thousand grains weight of 29.7 g was observed in plots where conventional of tillage were used. Similarly heavier 1000 grain weight of 28.25 g was taken by mungbean variety NM-93 while less 1000 grains weight of 25.41 by NF9M12-12 variety of mungbean.

Grain yield of mungbean was significantly affected by tillage systems (Table 2). Highest grain yield (402 kg ha⁻¹) was noticed in the plots where MaxT was used while low grain yield (362 kg ha⁻¹) was obtained from the plots under zero tilled plots. The grain yield ranged from 381 to 384 kg ha⁻¹ in different varieties.

Discussion

Varieties and tillage system had non-significant effect on days to emergence. Days to emergence depend basically on seed quality, and nutrient availability because equal doses of nitrogen and phosphorus were applied to all plots, therefore no such differences in days to emergence as affected by different tillage systems and mungbean varieties were found. In contrast to our results, Hughes et al., [16] reported low emergence under zero tillage plots. But according to Jan et al., [17], maximum emergence m⁻² in mungbean was recorded in plots of conventional tillage system while minimum emergence m⁻² was recorded in plots of reduced tillage.

Plants m⁻² were more in plots where more number of tillage were applied. As number of tillage was decreased, the number of

plants emerged m^{-2} was also decreased because the compaction of soil increased. The higher tilled plot attained significantly greater plant height and better growth as compare with less tilled plant. This might be due to better pulverization of soil, which provide favorable condition for plant growth and nutrients were readily available in the soften plots than the sole used of tine cultivator twice. According to Amin et al., [18], taller plants in wheat were recorded while using chisel plow and moldboard plow, followed by rotavator than lone use of cultivator twice. Likewise our results, Amin et al., [19] reported that different tillage practices produced different plant height in mung bean. However, Aslam et al., [20] observed non- significant differences in plants m^{-2} among mungbean genotypes. Plots where conventional and maximum tillage was used produced significantly more number of pods plant^{-1} as compared with the other plots. In plots where more number of tillage were used produced more number of pods plant^{-1} due to vigorous growth, more number of branches plant^{-1} and strong stem of the plant which resulted in more number of pods plant^{-1} . According to Jan et al., [17], the highest number of pods plant^{-1} in plots applied reduced tillage system while minimum was recorded in plots of conventional tillage system. According to Khan et al., [10], genotypes did not differ significantly from each other in number of pods plant^{-1} . These results might be due to differences in genetic make-up or climatic conditions of crop plants. Number of grains pod^{-1} was significantly not affected by both tillage and varieties. Number of grains pod^{-1} depend on genetic makeup of the varieties and seeds of good quality, so therefore, no such difference were found in number of grains pod^{-1} as affected by different tillage and varieties of mungbean. Varieties and tillage system showed significant variation for biological yield as

well as number of branches plant^{-1} . Maximum tilled plots gave high biological yield. This may be due to softness of soil, better root system and better establishment of plants. Variety NM -93 produced more biological yield as compare with other varieties. According to Amanullah and Hatam [21-22], biological yield had positive relationship with plant height, branches and pods plant^{-1} in mung bean. The results are in confirmation with those of Bonari and Macchia [23], they reported that branches plant^{-1} and grain yield increased as the number of tillage increases. Our results are in disagreement with those of Salahin et al., [24], who reported that tillage had no significant effect on biomass and straw yield of mungbean. Our results are in agreement with those of Khan et al., [25], who reported that mould board plowing produced more biological yield than cultivator. Different tillage practice had significant effect on biomass yield in mungbean [19]. According to Jan et al., [17], maximum biological yield was recorded in plots where conventional tillage system was used, while minimum yield was recorded in plots under reduced tillage system. The difference in the biological yield of different varieties may be due to the differences in the genetic makeup of different varieties.

Varieties and tillage system had significant effect on 1000 grains weight. Heavier grains were produced by the plants of plots where maximum tillage system was used as compared to less tilled plots. Variety NF9M12-12 produced heavier 1000 grain weight as compare to other varieties of mungbean due to differences in genetic make-up of the variety. Variation in seed weight between varieties can be attributed to genetic make-up of the crop plants. According to many reports [26-28], there were significant differences in 1000 seeds weight of different mungbean genotypes. The differences among the 1000 grains

weight of different cultivars of mungbean might be due to hereditary superiority, growth rate, crop potential of yield, higher nutrients translocation, assimilation and dry matter partitioning [28]. The 1000 grains weight in mungbean under minimum tillage was higher than conventional tillage [17, 29].

Higher grain yield (kg ha^{-1}) was noticed in plots under maximum tillage plots because of heaviest seeds and production of higher number of pod plat^{-1} which results in higher grain yield. These results are in conformation with previous report [30], where suggested that grain yield depends on 1000 grain weight and number of pods plant^{-1} . Comparable yields of different crops under various tillage systems have also been reported by many researchers [31-34]. Higher grain yield was obtained from plots under conventional tillage system as compared to lower grain yield was in plots under reduced tillage system [17]. Deep tillage (45 cm) was considered more beneficial in terms of higher mungbean

productivity under un-irrigated condition, while shallow tillage (15 cm) was better under irrigated condition of Peshawar [1]. According to Hussain et al., [27], there was non-significant difference between mungbean varieties. In mungbean, the increase in grain yield of high yielding germplasm was due to the increase in seeds pod^{-1} , pods plant^{-1} and 100-seeds weight [21, 22].

Conclusion

We concluded from this research that mungbean variety “NM-92” performed better than other varieties in terms of better growth, higher yield and yield components. We also found that maximum tillage was better than other tillage practices by improving growth, yield and yield components of mungbean. On the basis of our results we recommend mungbean variety “NM-92” and maximum tillage practice to get higher mungbean productivity under dryland condition of Karak, Khyber Pakhtunkhwa.

Table 1. Emergence m^{-2} , days to emergence, number of branches plant^{-1} , plant height (cm) and number of pods plant^{-1} as affected by different tillage system and varieties of mungbean under dryland condition.

Varieties	Emergence m^{-2}	Days to emergence	Number of branches plant^{-1}	Plant height (cm)	Number of pods plant^{-1}
Local	17	6	4	53	16
NF9M12-12	18	6	4	53	19
NM-93	18	6	5	54	19
NM-92	19	6	5	54	20
LSD	ns	ns	ns	ns	ns
Tillage system					
Zero	12 c	6	4	42 d	15 c
Conventional	16 b	6	4	48 c	19 a
Minimum	19 b	5	5	57 b	19 a
Maximum	24 a	6	4	66 a	23 b
LSD	1.698	ns	ns	1.483	2.592
V x T	ns	ns	ns	ns	ns

Means followed by different letters within the same category are significantly different at 5% level of probability using Least Significant Difference (LSD) test.

Table 2. Number of grains pod⁻¹, biological yield (kg ha⁻¹), thousand grains weight (g) and grain yield (kg ha⁻¹) as affected by different tillage system and varieties of mungbean under dryland condition.

Varieties	Number of grains pod ⁻¹	Biological yield (kg ha ⁻¹)	Thousand grains weight (g)	Grain yield (kg ha ⁻¹)
Local	10	1825 c	27.00 ab	384
NF9M12-12	9	1899 ab	25.41 c	382
NM-93	9	1939 a	28.25 a	381
NM-92	10	1857 bc	26.08 bc	384
LSD	ns	64.2	2.084	ns
Tillage system				
Zero	9	1833 c	28.08 b	362 b
Conventional	9	1900 ab	29.75 a	391 ab
Minimum	10	1874 b	25.33 c	377 a
Maximum	10	1980 a	23.25 d	402 a
LSD	1.698	33.01	1.481	19.24
V x T	ns	ns	ns	ns

Means followed by different letters within the same category are significantly different at 5% level of probability using Least Significant Difference (LSD) test.

References

1. Amanullah, Majidullah, Khan I, Hussain Z & Kakar KM (2014). Phenomorphological traits of mungbean as influenced by phosphorous and tillage under irrigated and un-irrigated conditions. *Pure Appl Biol* 3(2): 55-59.
2. Amanullah. 2010. *Common bean (Phaseolus vulgaris L.): The unexploited but the potential food legume crop in the Northern Khyber Pakhtunkhwa-Pakistan (First Edition)*. Create Space, New York.
3. MINFAL (2005). Agric. Statistic of Pak. Ministry of Food, Agric and Livestock, Economic Wing, Islamabad.
4. Prihar SS (1990). Impact of tillage on soil physical environment. In: Abstracts. Applied Soil Physics in Stress Environment. 252-266. Jan 22-26, 1989 at PARC, Islamabad.
5. Simmons FW & Nafziger ED (2012). Soil Management and Tillage. Illinois Agronomy Handbook. <http://extension.cropsci.illinois.edu/handbook/pdfs/chapter10.pdf>.
6. Jenane C, Chaplin J & Lueders M (2012). A powered flail tool for residue manipulation in conservation tillage. For presentation at the International Seminar of the 3rd Section of the CIGR on Tillage in Arid and Semi-Arid Areas Rabat – Morocco.
7. Anon. 2003. Fertilizers and their use in Pakistan. An Extension Guide. p. 112. Nisar & Rashid (eds.). National Fertilizer Development Centre, Islamabad.
8. Mitchell JP, Lanini WT, Temple SR, Brostrom PN, Herrero EV, Miyao EM, Prater TS, Fouche B, Mullen RJ & Hembree KJ (2000). Conservation tillage initiatives in California. In: Proceedings of Conservation Tillage 2000: Conservation tillage Success Stories from around the U.S., Parlier, CA, USA. 83: 10–11.
9. Ayub M, Tanveer A, Choudhry MA, Amin MMZ & Murtaza G (1999). Growth and yield response of Mungbean (*Vigna radiata* L.) cultivars at varying levels of nitrogen. *Pak. J. Bio. Sci.* 2: 1378-1380.
10. Khan MA, Baloch MS, Taj I & Gandapur DI (1999). Effect of phosphorus

on growth and yield of mungbean. *Pakistan J. Biol. Sci.* 2(1): 667-669.

11. Yadav M & Warsi AS (1988). Performance of summer planted mungbean in relation to irrigation and plant density. *Indian J. Agron.* 33: 19-21.

12. Kirchof G, Priyono S, Utomo WH, Adisarwanto T, Dacany FV & So HB (2000). The effect of soil puddling on the soil physical properties and the growth of rice and post rice crops. *Soil and Tillage Res.* 56:37-50.

13. Naseem SB, Khan AH, Islam M, Mollah U & Ali MA (1977). Effect of seeding method and varying surface soil moisture on the stand establishment of mungbean (*Vigna radiata* L.). *Bangladesh J. Sci. Ind. Res.* 32: 295-301.

14. Amanullah & Shitab Khan (2011). Performance of high yielding wheat and barley cultivars under moisture stress. *Pak. J. of Bot* 43(4): 2143-2145.

15. Steel RGD, Torrie JH & Deekey DA (1997). *Principles and Procedures of Statistics: A Biometrical Approach*, 3rd edition, pp: 400-428. McGraw Hill Book Co. Inc. New York.

16. Hughes KA, Horne DJ, Ross CW & Julian JF (1992). A 10-year maize/oats rotation under three tillage systems: 2. Plant population, root distribution and forage yields. *Soil and Tillage Research* 22:145-157.

17. Jan AK, Alam, Amanullah & Stewart BA (2012). Mungbean response to tillage systems and phosphorus management under moisture stress condition. *J. plant Nutr.* 35(1): 21-33.

18. Amin M, Khan MJ & Jan MT (2013). Effect of tillage practices and sowing methods on weed and biological yield of wheat under semi-arid environment. *Pak J. Weed Sci. Res.* 19(1): 109-121.

19. Amin M, Khan MJ, Jan MT, Latif A, Rehman M, & Arif M (2014). Weed

biomass and growth of mungbean as affected by tillage practices and sowing methods. *Sarhad J. Agric.* 30(2): 227-232.

20. Aslam M, Hussain M, Nadeem MA & Haqqani AM (2004). Comparative efficiency of different mungbean genotypes under Agro climatic conditions of Bhakkar. *Pakistan J. Life Soc. Sci.* 2(1): 51-53.

21. Amanullah & Hatam M (2000a). Correlation between grain yield and agronomic parameters in mung bean. *Pak. J. of Bio. Sciences.* 3(8): 1242-1244.

22. Amanullah & Hatam M (2000b). Performance and distinguishing characters of promising mung bean germplasm. *Sarhad J. of Agric.* 16(3): 259-268.

23. Bonari E, & Macchia M (1999). Effect of tillage system on yield of mungbean. *Abstracted in Field Crops.* 10: 697-776.

24. Salahin N, Islam MS, Begum RA, Alam MK & Hossain KMF (2011). Effect of tillage and integrated nutrient management on soil physical properties and yield under tomato-mungbean pattern. *Int. J. Sustain Crop Prod.* 6:58-62.

25. Khan RU, Rashid A, Khan MS & Shah A (2011). Impact of tillage practices on growth and seed yield of mungbean (*Vigna radiata* L.) under rainfed conditions. *J. Agric. Res.* 49: 195-201.

26. Ali A, Malik MA, Ahmad R & Atif TS (1996). Response of mungbean to potassium fertilizer. *Pak J Agric Sci* 33 (1-4): 44-45.

27. Hussain F, Malik AU, Haji MA & Malghani AL (2011). Growth and yield response of two cultivars of mungbean to different potassium levels. *J Animal & Plant Sci* 21(3): 622-625.

28. Uddin MS, Amin AKMR, Ullah MJ & Asaduzzman M (2009). Interaction Effect of Variety and Different Fertilizers on the Growth and Yield of Summer Mungbean. *American-Eurasian J Agron* 2(3): 180-184.

29. Dos S, Barreneche HP, Lhamby JC & Spera ST (1996). Soybean yield associated to different soil tillage methods and crop rotations systems. *Soil and Tillage Res.* 36: 21-29.
30. Broadbent FE & Reisenauer HM (1994). Crop yield and nutrient uptake by mungbean as affected by tillage. *J Plant Nutr* 17: 561-577.
31. Zorita MD (2000). Effect of deep-tillage and nitrogen fertilization interactions on dryland corn (*Zea mays* L.) productivity. *Soil Till Res* 54: 11-19.
32. Baumhardt RL & Jones OR (2002). Residue management and tillage effects on soil water storage and grain yield of dry land wheat and sorghum for a clay loam in Texas. *Soil Till Res* 68:71-82
33. Schlegel AJ, Dhuyvetter KC, Thompson CR & Havlin JL (1999). Agronomic and economic impacts of tillage and rotation on wheat and sorghum. *J Prod Agric* 12: 4: 629-636
34. Ijaz SS & Ali S (2007). Tillage and mulch effects on profile moisture dynamics fallow efficiency and rain fed wheat yield in Pothwar. *Pakistan J Agric Res* 44: 90-95.