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EFFECT OF TILLAGE AND CROP RESIDUES MANAGEMENT ON MUNGBEAN (*VIGNA RADIATA* (L.) WILCZEK) CROP YIELD, NITROGEN FIXATION AND WATER USE EFFICIENCY IN RAINFED AREAS

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Abstract

A field experiment was conducted to study the effect of crop residues and tillage practices on BNF, WUE and yield of mungbean (*Vigna radiata* (L.) Wilczek) under semi arid rainfed conditions at the Livestock Research Station, Surezai, Peshawar in North West Frontier Province (NWFP) of Pakistan. The experiment comprised of two tillage i) conventional tillage (T1) and ii) no-tillage (T0) and two residues i) wheat crop residues retained (+) and ii) wheat crop residues removed (-) treatments. Basal doses of N @ 20: P @ 60 kg ha^{-1} were applied to mungbean at sowing time in the form of urea and single super phosphate respectively. Labelled urea having 5% ^{15}N atom excess was applied @ 20 kg N ha^{-1} as aqueous solution in micro plots (1m^2) in each treatment plot to assess BNF by mungbean. Similarly, maize and sorghum were grown as reference crops and were fertilized with ^{15}N labelled urea as aqueous solution having 1% ^{15}N atom excess @ 90 kg N ha^{-1}. The results obtained showed that mungbean yield (grain/straw) and WUE were improved in no-tillage treatment as compared to tillage treatment. Maximum mungbean grain yield (1224 kg ha^{-1}) and WUE (6.61kg ha^{-1} mm^{-1}) were obtained in no-tillage (+ residues) treatment. The N concentration in mungbean straw and grain was not significantly influenced by tillage or crop residue treatments. The amount of fertilizer-N taken up by straw and grain of mungbean was higher under no-tillage with residues-retained treatment but the differences were not significant. The major proportion of N (60.03 to 76.51%) was derived by mungbean crop from atmospheric N_2 fixation, the remaining (19.6 to 35.91%) was taken up from the soil and a small proportion (3.89 to 5.89%) was derived from the applied fertilizer in different treatments. The maximum amount of N fixed by mungbean (82.59 kg ha^{-1}) was derived in no-tillage with wheat residue-retained treatment. By using sorghum as reference crop, the biological nitrogen fixed by mungbean ranged from 37.00 to 82.59 kg ha^{-1} whereas with maize as a reference crop, it ranged from 34.74 to 70.78 kg ha^{-1} under different treatments. In comparison, non-fixing (reference) crops of sorghum and maize derived upto 16.6 and 15.5% of their nitrogen from the labelled fertilizer, respectively. These results suggested that crop productivity, BNF and WUE in the rainfed environment can be improved with minimum tillage and crop residues retention.

Introduction

Mungbean [*Vigna radiata* (L.) Wilczek] has been grown in the Indian subcontinent since very early times. It is an important summer pulse crop grown in Pakistan on 225.4 thousand hectares with an average grain yield of 577 kg ha^{-1} (Anon., 2006). Mungbean is used as split grain (dal*)*, in making soups, curries, noodles, bread and sweets, the seeds roasted with spices are also very popular. Mung is a good source of protein which averages between 22-24%.

Mungbean is a short duration legume and is grown under marginal condition of moisture stress and low soil fertility. It has a distinct advantage over other long duration summer legumes for utilization in various rotations and intercropping systems. Mungbean accumulates large amount of vegetation in a short period of time, so it could be used as a manure or as a cash cum soil improvement crop, by incorporating its residues into the soil after pods have been harvested at maturity. Like other leguminous crops, mungbean fixes atmospheric nitrogen through its symbiotic relationship with *Rhizobium* and *Bradyrhizobium*. Giller & Wilson (1991) reported estimates of N_2 fixed ranging from 23 to 250 Kg N ha^{-1} with a median of 110 kg N ha^{-1} for annual legumes with growth periods of 100 - 150 days.

Pakistan is predominantly an arid and semiarid country and agriculture is the mainstay of its economy. Of the total cropped area of 21.85 million ha in Pakistan, about 4 m ha are rainfed (Anon., 2006). Low productivity is the common feature of rainfed agriculture because of erratic and inadequate precipitation, very low organic matter content, soils erosion, poor physical condition, hardpan and other undesirable environmental conditions like dry air and high soil temperatures.

The plant nutrient uptake and soil physical conditions are closely related to soil organic matter content. About 98 % of the soil nitrogen is stabilized in the organic matter which is slowly released and in combination with other nutrients contributes to efficient crop production.

The use of crop residues as a source of plant nutrients is increasing in many parts of the world where inorganic fertilizers have not proved to be economically/environmently viable. At a time when there is increasing concern about decline in O.M content of soils, the use of crop residues may play an important role as a source of nutrients, O.M and as mulching materials. In such system, plant residue incorporation into soil provides a better physical condition for plant growth (Dalal & Chan, 2001; Dalal *et al*., 1998). After decomposition, the residue releases plant nutrients and builds up soil organic matter. Maintaining the crop residues on soil surface and involvement of legumes in crop rotation with minimum/no-tillage practices, can play an important role to sustain soil fertility, maintain organic matter, improve water use efficiency, physical conditions of soils and enhance crop productivity (Dalal & Chan, 2001; Dalal *et al*., 1998; Mason & Rowland, 1990; Heen & Chan, 1992; Gibson *et al*., 1992; Pedreno *et al*., 1996; Nowood, 1999) Kabir, 1999; Unger, 2000; Lampurlanes *et al*., 2001; Shah *et al*., 2003; Mohammad *et al*., 2003a, b).

In most rainfed area of Pakistan, due to poor soil fertility and low annual rainfall the farmers usually grow winter crops (wheat) and then leave the soil fallow. They conserve moisture from the summer rains in the soil until the time of sowing of a winter crop by combination of tillage practices. As the population of Pakistan is increasing rapidly, the demand for food, fiber etc is increasing. To meet the increasing demand for food, it will not be feasible to leave the land fallow. Under such situations, appropriate cropping system must be adopted to sustain soil fertility, and improve crop productivity.

Many researchers in Pakistan now advise the farmers to follow the principle of conservation agriculture in rainfed area for enhancing the soil organic matter and efficient utilization of nutrients and water. However, there is very little scientific information available as to how the crop residues and no-tillage practices will affect N_2 fixation and water use efficiency under rainfed conditions. Keeping in view the above facts, this experiment was conducted to study the effect of crop residues and tillage/no tillage treatments on nitrogen fixation, water use efficiency and yield of mungbean and soil fertility under rainfed conditions.

Materials and Methods

A field experiment was conducted at Livestock Research Station, Surezai, Peshawar, North West Frontier Province (NWFP), Pakistan. The experiment consisted of two tillage treatments (tillage and no-tillage) and two crop residues treatments (wheat crop residues retained (+) and wheat crop residues removed (–).

Experimental design and sowing: Experiment was laid out according to the split plot design, keeping tillage treatments as main plot, and crop residues as the sub plot. The size of the sub plot was 30 m^2 and was replicated 4 times. Under conventional tillage, 15-20 cm deep moldboard ploughing (tractor-driven) was applied and cultivation was done before the rainy season (July and August) at sowing time followed by planking while the zero- tillage was left undisturbed. After the first crop (wheat), plus-residue and minus- residue plots were established. Sowing of mungbean (cv. Ramazan) was done on July 26, 2005 with hand drill and recommended row to row distance of 30 cm was maintained. Fertilizers were applied @ 20 kg N and 60 kg P ha^{-1} to mungbean crop in the form of urea and single super phosphate, at sowing time. Mungbean was harvested on October 4, 2005.

Experimental site description: The experimental site is located at 33^o 45’ N and 70^o 50’ E at an altitude of 525 m above sea level near Peshawar and has cool climate in winter and warm to hot in the summer. The site falls under the Semi-Arid Zone. The annual rainfall during the last many years ranged between 200 mm to 1057 mm with an average of about 435 mm. The most humid month is August (76.7mm) followed by March (73.7mm) while June (11.6mm) and October (13.4 mm) are the driest months.

The evapotranspiration range is narrow during December to March (36-85mm) and highest in June (202mm). The mean monthly maximum temperature ranged from 17.6 to 39.3^{o}C and the minimum temperature from 1.7 to 24.1^{o}C. The highest monthly temperature is around 43^{o}C in June and the lowest –3^{o}C in December. The average Relative Humidity (R.H) ranges from 54 (June) to 72.6% (August). Composite soil samples from the experimental field were collected before sowing and analyzed for various parameters. The soil particle size analysis indicated that the proportion of sand in the soil profile ranged between 21 and 42%, silt between 32 and 42%, and clay ranged between 26 and 37%. The content of organic carbon in the surface (0-15 cm) soil was 0.52%, which gradually decreased to 0.24% at lower (30-60 cm) depth. The content of total nitrogen varied from 0.05% at 0-15 cm to 0.032% at 30-60 cm depth. The available phosphorus (P) was 5.33 µg P g^{-1} soil at 0-15 cm and decreased to 2.5 µg P g^{-1} soil at 30-60 cm depth. The soil was alkaline in reaction (pH 7.6-7.9), non-saline (EC 0.39-0.22 dSm^{-1}) and moderately calcareous in nature (11.6 to 18.5% lime) having bulk density of 1.43 to 1.45 Mgm^{-3}.

Biological nitrogen fixation studies: For N_2 fixation study, the mungbean crop in micro plots (1m^2) was fertilized with ^{15}N labelled urea as aqueous solution having 5% ^{15}N atom excess @ 20 kg N ha^{-1} at sowing time. While the reference crops (maize and sorghum) were fertilized with ^{15}N labelled urea as aqueous solution having 1% ^{15}N atom excess @ 90 kg N ha^{-1}. The whole micro-plots of mungbean were harvested at maturity. Similarly reference crops were also harvested on the same day and data on total biomass was recorded. After air drying, plant samples were dried in oven at 70^{0}C and finely ground (< 0.1 mm) in a Willey’s Mill and was analyzed for total N and ^{15}N analysis on mass spectrometer by IAEA staff at Seibersdorf laboratory, Austria. Nitrogen fixation was measured by the ^{15}N Isotope Dilution (ID) technique (Anon., 2001).

Moisture determination: Neutron probe was calibrated at the site for soil moisture determination before the start of the experiment. To monitor the effect of treatments (tillage/ no-tillage, crop residues) on the soil water storage, neutron access tubes down to 90cm soil depth were installed in each treatment in three replications. Neutron probe readings along with meteorological observations were recorded regularly. The water use efficiency was calculated according to water balance approach (Kirda, 1990).

Yield data and processing: For the yileld data, the mungbean crop in the whole macroplot was harvested at its physiological maturity. The pods were removed manually. After drying the grain and straw yield data was recorded.

Statistical analysis: The data was analyzed statistically and the means were compared using the computer MSTAT C programme (Steel & Torrie, 1980).

Results and Discussion

Yield: The yield of mungbean as influenced by tillage and crop residues is given in Table 1. The no-tillage plus wheat crop residues retained treatment produced significantly higher yield of mungbean straw. However, almost similar mungbean grain yield was obtained under both tillage and no-tillage systems in crop residues retained treatment. The grain and straw yield data indicated that crop residues in both tillage and no-tillage system enhanced the mungbean crop productivity under rainfed moisture stress condition. The increase in yield in crop residues retained treatment may be due to improvement in organic matter content of soil and water use by the crop. The effect of crop residues on yield is more clearly indicated in no-till system. The soil analysis results support these results as the organic matter, total N and mineral N were greater in the no-tillage with plus residues treatments than in no-residues treatments.

The minimum/zero-tillage practices and maintaining the crop residues on soil surface play an important role to sustain soil fertility, improving water use efficiency, physical conditions of soils and enhance crop productivity (Dalal & Chan 2001; Dalal *et al*., 1998; Heen & Chan, 1992; Gibson *et al*., 1992; Francis *et al*., 1992; Pedreno *et al*., 1996; Nowood, 1999; Unger, 2000; Lampurlanes *et al*., 2001; Shah *et al*., 2003; Mohammad *et al*., 2003 b). The minimum / zero tillage practices and crop residue retention on soil surface provide better physical soil condition for organic matter maintenance and conservation of moisture and thus contribute to sustainable crop productivity.

Table 1. Straw and grain yield of mungbean as influenced by tillage and crop residues treatments.

Tillage	Straw yield (kg ha^{-1})			Grain yield (kg ha^{-1})		
	Crop residues					
	+	-	T-Mean	+	-	T-Mean
T_0	2708.7 a*	1665.0 b*	2186.8 a	1213.7 a	928 b	1070.8 a
T_1	1789.0 b	1022.7 c	1405.8 b	1196.0 a	832 b	1014.0 a
R-Mean	2248.8 a	1343.8 b		1204.8 a	880 b	

T_1 = Conventional tillage; T_0 = No tillage; T-Mean = Tillage Mean; R-Mean = Crop residues Mean; + = Crop residue retained; - = Crop residue removed; * = The symbols show statistical significance in horizontal rows

Table 2. Nitrogen yield and fertilizer-N yield parameters of mungbean as influenced by tillage and crop residues treatments.

Tillage	Straw			Grain		
	+ Residues	**- Residues**	**T- Mean**	**+ Residues**	**- Residues**	**T- Mean**
			N content (%)			
To	2.14	2.01	2.07	4.50	4.29	4.39
T1	1.83	1.95	1.89	4.56	4.55	4.55
R-Mean	1.98	1.98		4.53	4.42	
			N Yield (kg ha^{-1})			
To	54.03	32.95	43.50	53.92	39.15	46.53
T1	32.80	19.98	26.39	54.44	37.90	46.17
R-Mean	43.41	26.46		54.18	38.52	
			N derived from fertilizer (%)			
To	4.47	3.77	4.12	4.48	4.41	4.44
T1	4.67	5.09	4.88	5.13	5.60	5.36
R-Mean	4.57	4.43		4.80	5.04	
			Fertilizer-N yield (kg ha^{-1})			
To	1.86	1.22	1.54	2.35	1.71	2.03
T1	1.47	1.06	1.26	2.77	2.05	2.41
R-Mean	1.66	1.14		2.56	1.88	

T_1 = Conventional tillage; T_0 = No tillage; **+** Residues = Crop residue retained; **-** Residues = Crop residues removed, T-Mean = Tillage mean, R-Mean = Crop residues mean

N yield and fertilizer N-yield parameters: The N concentration in mungbean straw and grain was not significantly influenced by tillage or crop residue treatments (Table 2). However, the N content in straw was slightly higher (2.14%) in no-tillage systems plus residues treatment as compared to no-tillage with crop residues removed treatment (2.01%). However, the N content in grain increased (4.50%) in the residue plus treatment in no-till system as compared to residues minus plots (4.29%) but almost similar grain N contents were recorded in conventional tillage system in both + and – residues treatments. In over all the N-content in grain was improved by tillage treatment. The nitrogen uptake by straw (N yield) was, however significantly greater (54.03 kg ha^{-1}) in no-tillage with residue retained treatment than residues removed treatment (32.95 kg ha^{-1}). In grains, the tillage had no effect on N uptake but residues retained treatment significantly increased the N yield (54.18 kg ha^{-1}) than that in residues removed treatment (38.52 kg ha^{-1}). The results showed that N-uptake by straw was reduced by tillage practices but the crop residues retained treatment in both conventional tillage and no-tillage system improved the N-uptake of mungbean grain and straw. The proportion of nitrogen derived by mungbean (both grain and straw) from the applied fertilizer (Ndff) was slightly higher under tillage treatment (Table 2). The Ndff in both mungbean grain and straw was slightly enhanced by crop residues retained treatment in no-tillage system but Ndff was not improved by crop residues retained treatment in conventional tillage system. The possible reason for Ndff improvement by mungbean in no-tillage with crop residues retained treatment might be due to lower soil surface temperature and water evaporation that might have helped to reduce the N-losses from fertilizer. It was found by Nesmith *et al*., 1987 that no-tillage with crop residues resulted in soil surface temperature 5 to 8^{o}C lower than temperatures measured on bare soil. Also, water content of the upper 0.10 m of soil in the no-tillage nonburned treatment was as much as 30 to 40% higher than disk tillage and moldboard plow.

The amount of fertilizer-N yield by straw of mungbean was slightly higher (1.86 kg ha^{-1}) under no-tillage and residues treatment while in grain, tillage plus residues retained treatment showed higher fertilizer N yield (2.77 kg ha^{-1}). The crop residues retained treatment in both tillage and no-tillage system improved the fertilizer N-yield of mungbean grain and straw.

Water use efficiency: The water use efficiency (WUE) of mungbean as influenced by tillage and crop residues management treatments is summarized in Table 3. The grain/straw water use efficiency was enhanced in no-tillage treatment as compared to conventional tillage. Maximum straw (13.36 kg $ha^{-1}mm^{-1}$) and grain WUE (6.61 kg $ha^{-1}mm^{-1}$) was found under no-tillage plus residues retained treatment. The crop residues in no-tillage treatment reduced the evaporation of moisture from soil and soil temperature and enhanced soil fertility that might have improved the yield and water use efficiency. The crop residues in no-tillage system remained on soil surface and worked as mulching material. Thus in no-tillage system crop residues play a dual role as a mulching material as well as soil organic matter improvement. Soil surface conditions are of major importance in determining the water content of soil under different tillage systems. The no-tillage was potentially found better for semiarid region because it maintained greater water content in the soil and greater root growth especially in years of low rainfall (Lampurlanes *et al*., 2001).

Nitrogen fixation: The major proportion of N (58.20 to 76.51%) was derived by mungbean crop from atmospheric fixation; the remaining proportion (19.6 to 35.91%) was taken up from the soil and a small proportion (3.89 to 5.89%) of its plant-N was derived from the applied fertilizer in different treatments (Table 4). In comparison, sorghum and maize derived upto 16.6 and 15.5% of its nitrogen from the labeled fertilizer respectively. Maximum amount of N (82.59 kg ha^{-1}) was derived from fixation by mungbean in no-tillage plus crop residues retained treatment. In overall, the no-tillage enhanced the N_2 fixation as compared to tillage treatment. The crop residues retained enhanced the N_2 fixation in both till and no-tillage system. However, the crop residues effect on N_2 fixation was more clearly indicated in no-tillage system than tillage. The results of soil analysis collected after harvest of mungbean crop showed that crop residues enhanced the O.M. content that might have improved the biological activity which resulted in higher N_2 fixation and spare more mineral N in soil. These results are supported by those of Shah *et al*., (2003) who report that characteristics of legumes to fix atmospheric nitrogen not only support the growth of their own plants without nitrogen fertilizer application, but also spare some if not most of its biologically fixed N in soil for the subsequent crop.

The mungbean tested variety (cv. Ramazan) is a newly released commercial cultivar and produce higher yield than national average yield. In addition, it has maximum BNF capacity as recorded in our experiment under drought condition. The nitrogen fixed by legumes from atmosphere depends on plant species, (Senaratne & Ratnasinghe, 1993), genotype variation (Kumaga *et al*., 1994), drought stress, (Kurdali, 1996), soil N status and N_2 fixation ability (Kumarasinghe *et al*., 1992). Mungbean is a summer crop and the temperature during its sowing time is usually above 40^{o}C in our area. Nesmith *et al*., 1987, reported that no-tillage with crop residues helps to reduce soil surface temperature from 5 to 8^{o}C than temperatures measured on bare soil. The improvement in Biological Nitrogen Fixation (BNF) in residues retained treatment in this experiment may be due to lower soil temperature that enhanced microbial activity and nodulation. These results indicated that crop residue and no-tillage enhanced the N_2 fixation under rainfed dry condition. These findings were supported by Zotarelli *et al*., (2002) who described that BNF contribution by soybean in the areas of south Brazil was 82.4% under no-tillage as compared to 70.9% in conventional tillage where BNF contribution by lupins under no-tillage was 74.4% while 68.8% under conventional tillage.

Table 3. Straw and grain water use efficiency of mungbean as influenced by tillage and crop residue treatments.

Tillage	Straw water use efficiency ($kg\ ha^{-1}mm^{-1}$)			Grain water use efficiency ($kg\ ha^{-1}mm^{-1}$)		
	Crop residue					
	+	-	T-Mean	+	-	T-Mean
T_0	13.36	8.26	10.81	6.61	5.11	5.86
T_1	9.21	7.52	8.36	6.58	5.65	6.11
R-Mean	11.26	7.89		6.59	5.38	

T_1 = Conventional tillage; T_0= No tillage; + = Crop residues retained; - = Crop residues removed; T- Mean = Tillage mean;, R-Mean = Crop residues mean

Table 4. Nitrogen derived by mungbean (N fixing system) and sorghum/maize (Non fixing system) from fertilizer, and the amounts of N fixed by mungbean from atmosphere as influenced by tillage and crop residues treatments.

Tillage	Crop residue	a. % Non-fixing system (sorghum/maize)			Fixing system (mungbean)		
		Total N yield ($kg\ ha^{-1}$)	Total Fert-N yield ($kg\ ha^{-1}$)	N dff. (%)	Total N yield ($kg\ ha^{-1}$)	Total Fert-N yield (kg/ha)	N dff. (%)
		Non-fixing: Sorghum					
T_1	+	109.45	15.07	14.06	87.24	4.24	4.87
	-	70.40	10.24	14.89	57.88	3.11	5.37
T_0	+	180.53	29.63	16.56	107.95	4.20	3.89
	-	160.79	22.68	14.09	72.10	2.93	5.89
		Non-fixing: Maize					
T_1	+	48.16	6.41	13.29	87.24	4.24	4.87
	-	43.34	6.04	13.54	57.88	3.11	5.37
T_0	+	65.55	7.40	11.30	107.95	4.20	3.89
	_	59.80	8.47	15.49	72.10	2.93	5.89

b. Nitrogen derived by mungbean from atmospheric fixation

Tillage	Crop residue	Proportion (%)			Amounts ($kg\ ha^{-1}$)			
		Ndff	Ndfa	Ndfs	Ndff	Ndfa	Ndfs	Total
		Non-fixing: Sorghum						
T_1	+	4.87	65.36	29.77	4.24	57.03	25.97	87.24
	-	5.37	63.93	30.70	3.11	37.00	17.77	57.88
T_0	+	3.89	76.51	19.60	4.20	82.59	21.16	107.95
	-	5.89	58.20	35.91	2.93	41.96	27.21	72.10
		Non-fixing: Maize						
T_1	+	4.87	63.36	31.77	4.24	55.29	27.71	87.24
	-	5.37	60.03	34.60	3.11	34.74	20.03	57.88
T_0	+	3.89	65.57	30.54	4.20	70.78	32.97	107.95
	-	5.89	61.20	32.91	2.93	44.12	25.05	72.10

T_1 = Conventional tillage; T_0 = No tillage, + = Crop residue retained; - = Crop residue removed, Ndff = Nitrogen derived from fertilizer, Ndfa = Nitrogen derived from atmosphere, Ndfs= Nitrogen derived from soil

Evaluation of Reference crops for BNF: The choice of an appropriate non-fixing reference crop is the most important factor for measuring N_2 fixation by using ^{15}N enrichment technique. In this experiment, two cereal crops (maize & sorghum) were used as reference crops to study biological nitrogen fixed by mungbean.

The results indicated (Table 4) that small difference in BNF was noted by using these reference crops under different treatments. In tillage with no residues (T_1 -) treatment, BNF by mungbean was 37.00 and 34.74 $kg\ ha^{-1}$ by using sorghum and maize as reference crops, respectively. Similarly under tillage with residues retained (T_1+) treatment, it was 57.03 and 55.29 kg ha^{-1}, under no-tillage without residues retention (T_0 -) treatment, 41.96 and 44.12 kg ha^{-1}, respectively. However, in no-tillage with crop residues retained (T_0+) treatment, 82.59 and 70.78 kg ha^{-1} BNF was recorded by using sorghum and maize as reference crops respectively and the differences seems to be higher than the rest of treatments. Overall, in case of sorghum, the BNF by mungbean ranged from 37.00 to 82.59 kg ha^{-1} whereas in maize it ranged from 34.74 to 70.78 kg ha^{-1}. Therefore it is concluded from above results that both maize and sorghum can be used as reference crops for mungbean BNF studies under rainfed condition.

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