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Effects of herbicides and tillage practices on weeds and summer mungbean (*Vigna radiata*) in wheat (*Triticum aestivum*)-mungbean cropping sequence

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ABSTRACT

A field experiment was conducted at ICAR-Indian Agricultural Research Institute to study the weed management strategy in zero-tillage (ZT) and conventional tillage (CT) with and without residue during 2014 and 2015 in summer mungbean [*Vigna radiata* (L.) Wilczek] following residual effects of 4 weed control treatments, comprising of ready-mix and sequential application of herbicides during previous *rabi* seasons, 2013-14 and 2014-15 in wheat (*Triticum aestivum*). Previous season weed-control treatment significantly reduced the broad-leaved, narrow-leaved and total weed population and dry weight in both the years over unweeded control. However, herbicidal treatments did not differ significantly adopted during previous *rabi* season. Results showed that ZT with residue retention (ZT+R) caused a significant reduction in population and dry weight of weeds compared to CT without residue. Mungbean yield attributes were higher in ZT with residue retention (ZT+R) than conventional-tilled treatments. Previous applied of pendimethalin 1 kg/ha followed by sulfosulfuron 25 g/ha combined with ZT with 5 tonnes/ha residue retention (ZT+R) +75% N + rest N based on GreenSeeker™ (GS) resulting in higher mungbean yield, may be recommended for mungbean production in north-western Indo-Gangetic plains of India in wheat-mungbean sequence.

Key words: Conventional tillage, Herbicides, Mungbean, Wheat, Zero tillage

Mungbean [*Vigna radiata* (L.) Wilczek] is one of the most important pulse crops in India. It has wider adaptability and is grown in different seasons under varied agroclimatic conditions in the country. Mungbean can be a sequential partner of this cropping system during summer (April–June) under assured irrigation facility. Inclusion of mungbean in this double cereal based cropping system particularly under conservation agricultural practices can be future drivers of agricultural change in the north-western Indo-Gangetic Plains of India (Gathala *et al*. 2013). Therefore, the conservation agricultural practices in wheat and their positive effect on succeeding mungbean crop needs to be studied. Weeds are one of the major causes for the poor yield of mungbean. Being a short duration crop, it faces heavy weed competition right from the early growth stages (Pandey *et al*. 1999). Uncontrolled weeds may reduce mungbean yield by 50-90% depending upon cultivars, soil type, soil moisture level and other environmental conditions (Kumar *et al.* 2006). Increasing costs and unavailability of labor particularly during the peak period, has led to the use of herbicides. Chemical control weed forms an excellent alternative to manual as well as mechanical weeding and provide weed-free environment from emergence up to 30-35 days (Dungarwal *et al.* 2003, Das and Yaduraju 2011, 2012). The mixture (tank-mix, ready-mix) and sequential application of different herbicides as pre- or post-emergent in May have the residual effect on succeeding crop particularly under conservation agriculture (CA). The use of minimum tillage and residue retention on surface soil under CA can alter the degradation of herbicides (Kurchania *et al*. 1989). Sometimes, the residual effect of previous season applied herbicides may check the weed growth in sequential crop (Kaur and Brar 2014). It ultimately leads to labor and cost-saving as no herbicides need to apply succeeding crop. Therefore, there is a need to study the residual effect of previous season applied herbicides in wheat on succeeding summer mungbean crop to get better productivity, profitability and sustainability.

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MATERIALS AND METHODS

A field experiment was carried out during summer seasons of 2014 and 2015 at the ICAR-Indian Agricultural Research Institute, New Delhi, on plots applied with 4 weed control treatments in the previous *rabi* seasons superimposed with conventional till and no-till systems (with and without residue) during summer in mungbean. The climate of the research farm is semi-arid with dry hot summer and cold winters. May and June are the hottest months with mean daily maximum temperature varying from 40 to 46^{o} C, while January is the coldest month with mean daily minimum temperature ranging from 6 to 8^{o} C. The mean annual rainfall is 710 mm, of which 80% is received during southwest monsoon from July to September and the rest is received through 'Western Disturbances' from December to February. The treatments in wheat were comprising of conventional tillage without residue + 100% N (based on soil test value) (CT-R+100% N), conventional tillage + 5 tonnes/ha maize residue incorporation + 100% N (CT+R+100% N), conventional tillage + 5 tonnes/ha maize residue incorporation + 75% N + rest N based on green seeker (GS) (CT+R+75% N+GS), zero tillage without residue + 100% N (ZT-R+100% N), Zero tillage + 5 t/ha maize residue retention + 100% N (ZT+R+100% N) and zero tillage + 5 tonnes/ha maize residue retention + 75% N + rest N based on green seeker (ZT+R+75% N+GS) in main plot and 4 weed control treatments, viz. unweeded control (UWC), weed free check (WFC), sulfosulfuron 75% WP + metsulfuron methyl 5% WP ready-mix herbicide @ 40 g/ha as post emergence (SSF+MSM) and pendimethalin (1 kg/ ha) as pre-emergence followed by sulfosulfuron (25 g/ha) post-emergence (PMT-SSF) in sub-plot. Soil was sandy loam, pH 7.9, organic C (0.60%), low in available nitrogen (220.6 kg/ha), medium in P (15.2 kg/ha) and K (260 kg/ha). In *kharif* season, maize crop was grown with the stipulated treatments and residue was applied in *rabi* season wheat and wheat residue was applied to mungbean and at the end of mungbean season wheat residues were partially decomposed. All the treatments except weed-free check were not disturbed in mungbean just to find out the residual effect of the *kharif* season treatments. In weed-free check, the plots were maintained free of weeds through manual weeding as and when required. Conventional tillage (CT) plots were ploughed by a tractor-drawn disc plough followed by planking. Previous season wheat residue was retained on ZT with residue plots and ZT with no residue plot was left undisturbed. A pre-sowing irrigation was given to entire field to facilitate smooth germination of mungbean. Mungbean SML 668 was sown by a happy seeder with a 20 kg/ha seed rate along with 100 kg DAP/ha. For sequential application of herbicides, pendimethalin @ 1 kg/ha and sulfosulfuron 25 g/ha were applied separately in the required amount with 400 l water/ha by knapsack sprayer. For ready-mix herbicide 'total' (sulfosulfuron 75% WP + metsulfuron methyl 5% WP) product basis, 40 g/ha was applied using a knapsack sprayer fitted with a flat fan nozzle at 25 days after sowing (DAS). An area of 0.25 m^2 was selected randomly at two spots by throwing a quadrat of 0.5 m × 0.5 m, weed species were counted from that area, and population was expressed in number/m^2. The collected weeds were first sun-dried and then kept in an electric oven at 70^{0}C till the weight became constant, and dry weight was expressed as g/m^2. As wide variation existed in data, number and dry weight of weeds were transformed through square-root [$\sqrt{(x+0.5)}$] method before analysis of variance.

Weed control efficiency (WCE) and weed control index (WCI) were calculated at 30 DAS (Das 2008) using the following formula and expressed in per cent:

$$\text{WCE (\%)} = \frac{\text{Weed population in unweeded control plot} - \text{Weed population in treated plot}}{\text{Weed population in unweeded control plot}} \times 100$$

$$\text{WCI (\%)} = \frac{\text{Dry weight of weed (g) in unweeded control plot} - \text{Dry weight of weeds (g) in treated plot}}{\text{Dry weight of weeds (g) in unweeded control plot}} \times 100$$

Periodical picking of mungbean was taken and sun-dried and threshing was done. Data on grain yield were recorded from the net plot, whereas yield attributes from five randomly selected plants at harvest. The data were analyzed as for the split-plot design, tillage, residue and nitrogen as the main-plot treatment and weed control practices as the sub-plot treatment, using the analysis of variance (ANOVA) by windows based SPSS programme (ver. 16.0, SPSS Inc. 1996) to determine the statistical significance of treatment effects. Differences were considered significant at 5% level of significance.

RESULTS AND DISCUSSION

Weed competition

Five weed species, three broad-leaved, viz. *Trianthema portulacastrum* L., *Digera arvensis* Forsk., and *Amaranthus viridis* and two narrow-leaved, viz. *Echinochloa colona* (L.) Link., and *Cyperus rotundus* L. were present in mungbean. Differences in population of broad-leaved weeds at 30 DAS due to tillage, residue, nitrogen and weed management practices across the years were significant and lower weed population was observed in second year than that of first year (Table 1). Among the different tillage, residues and N management practices, CT-R+100% N was not found effective in reducing the population of broad-leaved weeds as these treatments caused significantly more population of broad-leaved weeds compared to the ZT-R+100% N, ZT+R+100% N and ZT+R+75% N+GS at 30 DAS. The UWC treatments caused significantly more population of broad-leaved weeds compared to remaining previous season applied weed control treatments at 30 DAS. Among the herbicidal treatments, PMT-SSF and SSF+MSM were on a par for controlling of broad-leaved weeds. Differences in population of narrow-leaved weeds at 30 DAS due to tillage, residue, nitrogen and weed management practices across the years were non-significant (Table 1). At 30 DAS, the significantly lower narrow-leaved weeds population was in ZT+R+75% N+GS than remaining tillage, residue, N management treatments. Pooled data

Table 1 Total broad-leaved, narrow-leaved and cumulative weed population at 30 DAS as influenced by previous season tillage, residue, nitrogen and weed management practices in mungbean (pooled of two years)

Treatment	Total broad-leaved weed population (No./m^2) at 30 DAS	Total narrow-leaved population (No./m^2) at 30 DAS	Total weed population (No./m^2) at 30 DAS
First year	3.70 (177.4)	4.28 (205.4)	5.71 (274.2)
Second year	3.06 (146.9)	4.04 (193.7)	5.15 (247.2)
SEm ±	0.19	0.25	0.21
CD (P=0.05)	0.61	0.77	0.66
Tillage, residue and nitrogen management			
CT-R+100% N	4.60 (73.7)	4.97 (79.6)	6.84 (109.5)
CT+R+100% N	2.85 (45.6)	4.45 (71.2)	5.42 (86.8)
CT+R+75% N+GS	4.03 (64.5)	5.11 (81.8)	6.60 (105.6)
ZT-R+100% N	2.92 (46.7)	4.09 (65.4)	5.04 (80.7)
ZT+R+100% N	3.34 (53.4)	4.09 (65.4)	5.28 (84.5)
ZT+R+75% N+GS	2.53 (40.5)	2.24 (35.8)	3.39 (54.3)
SEm ±	0.34	0.43	0.36
CD (P=0.05)	1.06	1.34	1.13
Weed management			
UWC	7.13 (171.2)	7.57 (181.7)	10.44 (250.4)
WFC	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
SSF+MSM	3.04 (72.9)	4.59 (110.3)	5.54 (133.1)
PMT-SSF	3.35 (80.3)	4.47 (107.3)	5.74 (137.8)
SEm ±	0.19	0.22	0.24
CD (P=0.05)	0.54	0.63	0.70

showed that zero-tilled with residue treatments were superior to conventional-tilled treatments for reducing the broad-leaved and narrow-leaved weeds indicating the smothering effect residue laden plots on weed growth (Susha *et al*. 2014). Weed control treatments reduce the narrow-leaved weeds population than UWC. Among the herbicidal treatments, PMT-SSF and SSF+MSM were on par for controlling of narrow-leaved weeds but lower population was in PMT-SSF. A non-significant year wise variation of data in respect to total weed population was observed due to tillage, residues, N and weed management practices (Table 1). The CT-R+100% N was not effective in reducing the total population of weeds as these treatments caused significantly more population of total weeds compared to the ZT+R+75% N+GS. Herbicidal treatment significantly reduced the total weeds population than UWC in both years. In the entire situation zero-tilled with residue retention treatments had lower weed population. This indicated possible smothering effect of residues on weeds. Although, the different herbicidal application, i.e. sequential application of pre- and post-emergence and ready-mix application of post-emergence herbicides proved at par in respect to reduction weed population, but sequential application pendimethalin as pre-emergence followed by sulfosulfuron as post-emergence had an edge over the one time application of post-emergence herbicides in wheat. The application of herbicides might have reduced the seed bank which ultimately led to better weed control across all the tillage practices. The year-wise variation due to tillage, residue and N management practices at 30 DAS in respect to dry matter accumulation by weeds were significant and lower weed dry weight was obtained in second year than that of first year (Table 2). The pooled data of both the years data showed that ZT+R+75% N+GS significantly reduced the dry weight of weeds than CT-R+100% N and CT+R+75% N+GS. Application of PMT-SSF and SSF+MSM significantly reduced the dry weight of weeds. Among the previous season applied herbicidal treatments the effect of both the herbicides was at par in respect to weed dry weight. The more population and dry weight of weeds under conventional tillage may be due to the higher soil disturbance under conventional systems. Both the herbicides gave the satisfactory WCE and WCI. The residual effect of herbicides had considerable impact on succeeding crop as no herbicides were applied in mungbean. Although both the herbicides were on a par with regard to WCE and WCI, application of PMT-SSF gave better weed control and higher yield. In no-till systems, the occurrence of perennial weeds is more feasible, and changes in the temperature and light incidence on the soil surface influence dormancy of some weed species. The weed suppressive effects of crop residue have resulted in greater reduction of weeds in zero-tillage with residue (Christoffoleti *et al*. 2007, Das and Yaduraju 1999). Zero-till with crop residue management is an important multi-tactic approach to manage weed population dynamics in crop

Table 2 Total weed dry-weight, weed control efficiency and weed control index at 30 DAS as influenced by previous season tillage, residue, nitrogen and weed management practices in mungbean (pooled of two years)

Treatment	Total weed dry weight (g/m^2) at 30 DAS	Weed control efficiency (%)	Weed control index (%)
First year	8.34 (400.5)	47.02	42.61
Second year	7.08 (340.0)	49.12	42.74
SEm ±	0.22		
CD (P=0.05)	0.68		
Tillage, residue and nitrogen management			
CT-R+100% N	10.34 (165.4)	48.9	42.2
CT+R+100% N	6.81 (108.9)	47.1	33.7
CT+R+75% N+GS	9.76 (156.2)	46.4	37.8
ZT-R+100% N	8.09 (129.5)	46.6	42.6
ZT+R+100% N	7.76 (124.1)	46.6	36.7
ZT+R+75% N+GS	3.53 (56.4)	52.7	63.1
SEm ±	0.37		
CD (P=0.05)	1.18		
Weed management			
UWC	13.13 (315.1)	0.0	0.00
WFC	0.00(0.00)	100.0	100.00
SSF+MSM	8.69 (208.6)	46.7	37.43
PMT-SSF	9.03 (21.8)	45.6	33.27
SEm ±	0.25		
CD (P=0.05)	0.71		

rotations. Retention of crop residue on the soil surface under no-till systems can suppress weed seedling emergence, delay the time of emergence, and allow the crop to gain an advantage over weeds, and reduce the need for control.

Mungbean yield attributes and yield

Due to greater suppression of weeds compared to weedy check, the negative effect of weeds on mungbean yield attributes, viz. number of pods/plant, pod length (cm), grains/pod, 1 000-grains weight and yield was reduced by residual effect of previous season applied sequential and ready-mix herbicides (Table 3). All the yield attributing characters were higher in ZT+R+75% N+GS which was significant with CT-R+100% N. Mungbean yield (Table 4) differed significantly between tillage and previous season weed control measures in both the years and sequential application of pendimethalin 1 kg/ha as pre-emergence followed by sulfosulfuron 25 g/ha as post-emergence resulted in higher yield than un-weeded control (Table 4). Both the herbicides were on a par in respect to mungbean yield. ZT + R had significantly higher yield and yield attributes than conventional tillage probably, due to compensatory effects between yield components during growth and development of crop, and to a lower number of

Table 3 Yield attributes of mungbean as influenced by previous season tillage, residue, nitrogen and weed management practices (pooled of two years)

Treatment	Number of pods/plant	Pod length (cm)	Grains/ pod	1000- grains weight (g)
First year	17.2	8.3	8.8	45.2
Second year	18.2	7.4	9.7	47.6
SEm ±	0.3	0.1	0.1	0.1
CD (P=0.05)	0.8	0.4	0.3	0.3
Tillage, residue and nitrogen management				
CT-R+100% N	14.4	7.6	8.9	45.4
CT+R+100% N	18.2	7.7	9.1	46.1
CT+R+75% N+GS	17.8	8.0	9.2	46.9
ZT-R+100% N	17.1	7.7	9.2	46.1
ZT+R+100% N	18.5	8.0	9.3	46.6
ZT+R+75% N+GS	20.3	8.2	9.9	47.2
SEm ±	0.4	0.2	0.2	0.19
CD (P=0.05)	1.4	0.8	0.7	0.59
Weed management				
UWC	16.1	7.7	9.0	45.6
WFC	19.1	8.0	9.5	46.5
SSF+MSM	17.1	7.8	9.3	46.7
PMT-SSF	18.5	7.9	9.4	46.8
SEm ±	0.3	0.1	0.2	0.11
CD (P=0.05)	0.9	0.4	0.5	0.32

Table 4 Pod and grain yield of mungbean as influenced by tillage, residue, nitrogen and weed management practices (pooled of two years)

Treatment	Pod yield (tonnes/ha)	Grain yield (tonnes/ha)
First year	1.67	1.18
Second year	1.76	1.21
SEm ±	0.01	0.03
CD (P=0.05)	0.03	0.09
Tillage, residue and nitrogen management		
CT-R+100% N	1.47	1.06
CT+R+100% N	1.64	1.19
CT+R+75% N+GS	1.84	1.22
ZT-R+100% N	1.67	1.09
ZT+R+100% N	1.81	1.23
ZT+R+75% N+GS	1.86	1.38
SEm ±	0.02	0.05
CD (P=0.05)	0.05	0.15
Weed management		
UWC	1.61	1.06
WFC	2.01	1.26
SSF+MSM	1.61	1.22
PMT-SSF	1.64	1.23
SEm ±	0.01	0.04
CD (P=0.05)	0.04	0.11

weeds/m^2 (broad-leaved, grasses and total) in mungbean. This ultimately resulted in greater photosynthesis, and, hence, better translocation of photosynthates, besides larger sink and better N_2-fixation in mungbean and it was reflected in yield attributes. Also there may be a positive impact on soil water balance resulting from crop residue on the soil surface under no-till management. Residue from wheat was simulated to be especially effective in suppressing soil evaporation. This might have resulted in enhanced soil water retention and increased wheat yields. Fischer *et al*. (2002) reported that within the maize-wheat-mungbean rotation, ZT + R was clearly superior to the other tillage-residue combinations and during dry periods, showed less wilting. The use of surface residue coverage is an integral part of any successful conservation tillage system. Mungbean yield was influenced by growing season rainfall, and it was found to higher in the second year than in first year. As previously mentioned, sequential application of pendimethalin 1 kg/ha as pre-emergence followed by sulfosulfuron 25g/ha as post-emergence resulted in better control of weeds and higher wheat yield it will be more promising in the maize-wheat-mungbean cropping system because continuous use of sulfosulfuron and metsulfuron-methyl as post-emergence in wheat may hasten resistance development in weeds. Besides this, use of no ploughing and slightly higher moisture during sowing of wheat under conservation agriculture may invite early weed germination in wheat. Therefore, suitable weed management should be of paramount importance. Pendimethalin can be a good option in this regards.

Thus, the results show that the carry-over effect of ZT with 5 t/ha maize residue retention (ZT+R) +75% N + rest N based on GS resulted in significant reductions in weed growth (population and dry weight) and caused a considerable increase in the productivity of mungbean. This treatment was compounded with the effect of wheat residue also. The previous season sequential application of pendimethalin 1 kg/ha as pre-emergence followed by sulfosulfuron 25 g/ha resulted in better weed suppression and was superior to other weed control treatments. The effect of this treatment was more pronounced under ZT+R compared to other tillage treatments. Therefore, a combination of ZT with 5 t/ha maize residue retention (ZT+R) +75% N + rest N based on GreenSeeker^{TM} and sequential application of pendimethalin 1 kg/ha as pre-emergence followed by sulfosulfuron 25 g/ha can be recommended for better weed control and high wheat productivity and beneficial carry-over effect mungbeanin maize-wheat-mungbean cropping system in north-western Indo-Gangetic plains of India.

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