Life Science Studies

Journal homepage: www.journal.inrrd.com/lss

Original article

Jute Response to Residual Herbicides in Strip-Tilled Wheat: Growth and Challenges

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ARTICLE INFO

Article history
Received 14 January 2025
Revised 21 March 2025
Accepted 30 March 2025
Available online 03 April 2025

Keywords
Residues
Herbicides
Health impacts
Growth
Development

ABSTRACT

This study assessed the residual toxicity of herbicides on the growth and establishment of jute as well as on human health after strip tillage wheat cultivation. The experiment involved 18 treatments, including various combinations of pre-emergence, early post-emergence and post-emergence herbicides, along with weed-free and no-weeding controls. Jute seeds were sown in micro plots following wheat cultivation, and data were recorded on germination percentage, shoot and root lengths, leaf chlorophyll content, and dry weight. Results exhibited that most herbicides had no significant impact on jute germination and establishment, except for Triasulfuron followed by 2,4-D (T_{18}), which resulted in a reduction of 14.28% in plant population, likely due to residual toxicity. Conversely, treatments like Pretilachlor followed by Carfentrazone-ethyl (T_{10}) enhanced germination and plant population by 5.5%. Shoot and root lengths, and leaf chlorophyll content significantly improved in most herbicide treatments, with T_{18} achieving the highest chlorophyll content at 30 DAS. The dry weight of jute was positively affected in every treatment showing a significant relationship among shoot length and root length at 30 DAS. These findings suggest that while specific herbicides may pose residual toxicity risks, others can enhance subsequent crop growth, highlighting the importance of herbicide selection for sustainable conservation agriculture. These results provide valuable insights into weed management strategies, emphasizing the compatibility of herbicides with crop rotation systems to balance productivity and environmental sustainability.

Introduction

The demand for food increases with an increased number of populations which can only be achieved through the implementation of sustainable growing practices leading to a high yielding, profitable system with minimal environmental degradation (Shamim et al. 2020; Tilman et al. 2011). Conservation agriculture (CA) is a system designed to achieve agricultural sustainability by improving the biological functions of the agro-ecosystem with limited mechanical practices and judicious use of chemical inputs (Singh et al. 2020). In conventional farming, farmers would plough land to clean weeds and prepare it before sowing or planting. CA is the preferred option for crop production as it conserves the soil and stabilizes yields (Giller et al. 2015; Page et al. 2020). The shift from conventional tillage practices to conservation practices can be particularly difficult with respect to weed control. Despite both environmental and production advantages offered through conservation systems,

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adoption rates have previously lagged in many information, producer mindsets, and most countries due to several factors including: availability of required equipment, lack of importantly, weed control issues (Kells & Meggitt 1985; Baki et al. 2020). In systems with intense tillage operations, growers can obtain early season weed control through turning of the soil which disrupts weed seed germination and seedling growth through burial (Steckel et al. 2007). Minimum soil disturbance allows weed seeds to remain in the soil surface. To adopt conservation practices, growers initially face shifts in weed population dynamics due to altered distribution of weed seed within the soil (Chhokar et al. 2021); perennial weed species also thrive in reduced-tillage settings and can be difficult to control with available post-emergent herbicide options (Swanton et al. 1993; Ntombela 2019). Although studies report that, over time, the weed seed bank, or viable weed seed within the soil, will be reduced and/or easier to manage with chemical controls due to increased selection pressures and increased uniform germination, initial weed control strategies have remained challenging for agricultural lands being switched to conservation tillage practices (Murphy et al. 2006; Swanton et al. 2008). Successful weed control requires a producer's attention throughout the season to achieve an optimal harvest. CA system is more economic and environmentally friendly except for weed problems (Bajwa 2014). Weeds compete with crop plants, reduce yield and cause economic losses. Weed management practices are targeted to reduce crop production cost as well as increasing economic profitability with less adverse effect on soil and environment (Shah & Wu 2019). With the increase of labor cost, farmers are highly reliant on herbicidal weed control in their crops under CA system. The use of herbicide in a crop may affect the establishment of the succeeding crop under CA system. Crops are grown in different sequences in Bangladesh viz. T. Aman – wheat – mungbean, T. Aman – mustard – mungbean, T. Aman – wheat – sunflower, T. Aman – wheat – Aus rice. But the establishment and yield performance of the crops in a cropping pattern may be influenced by the herbicides used for weeding of the previous crops. Herbicide residue may persist in the soil which can affect the succeeding crops. The residual toxicity may vary in different herbicides. Therefore, there is a need for the evaluation of the residual effect of different herbicides on the establishment and growth of the succeeding crops. The information on the effect of herbicides applied in wheat on the following jute is scarce which led us to access the residual effects of the herbicides on jute.

Materials and methods

Experiment was carried out at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the month of March to June 2014. The experimental land was under subtropical region characterized by high temperature, high relative humidity, and heavy rainfall with occasional gusty winds during kharif season and scanty rainfall associated with moderately low temperature during rabi season. Jute (BJRI Tosa-2 (0-9897)) was cultivated as a test crop which was grown after harvesting wheat. The wheat was planted by strip tillage with VMP on 23 November and the crop was harvested on 19 March. Each experimental plot used in the experiments was used to grow the test crops in 1m x 1m micro plots. Eighteen treatments consists of No weeding (T_1), Weed free (Four hand weeding, T_2), Pendimethalin fb (followed by) Pendimethalin (T_3), Pretilachlor fb Pretilachlor(T_4), Pendimethalin fb Ethoxysulfuran (T_5), pretilachlor fb Ethoxysulfuran (T_6), Pendimethalin fb Ethoxysulfuran fb Carfentrazone-ethyl (T_7), Pretilachlor fb Ethoxysulfuran fb Carfentrazone-ethyl (T_8), Pendimethalin fb Carfentrazone-ethyl (T_9), Pretilachlor fb Carfentrazone-ethyl (T_{10}), Pendimethalin fb Pyrazosulfuran Ethyl fb 2,4-D (T_{11}), Pretilachlor fb Pyrazosulfuran Ethyl fb 2,4-D (T_{12}), Pendimethalin fb 2,4-D (T_{13}), Pretilachlor fb 2,4-D (T_{14}), Pendimethalin fb (Carfentrazone-ethyl + Isoproteuron) (T_{15}), Pretilachlor fb (Carfentrazone-ethyl + Isoproteuron) (T_{16}), Triasulfuron fb (Carfentrazone-ethyl + Isoproteuron) (T_{17}), and Triasulfuron fb 2, 4-D (T_{18}). In wheat cultivation the experiment was established in a Randomized Complete Block Design (RCBD) with three replications. The size of each unit plot was 3m × 4m. Three micro plots of 1m x 1m were prepared in each unit plot for jute to test the response of the treatments used in wheat plot. The jute was placed in micro plots and 500 Jute seeds were shown in broadcasting method. During cultivation of BARI Gom-26 (white variety) in November 2013, experimental land was infested by weeds which were killed by applying Glyphosate @ 100 mL ha-1. Pre-emergence herbicides (Pendimethalin, Pretilachlor and

Thiasulfuron) were applied at 03 days after sowing (DAS), early post-emergence (Ethoxysulfuran and Pyrazosulfuran ethyl) at 15 DAS and post-emergence herbicides (Carfentrazone-ethyl, 2, 4-D and Carfentrazone- ethyl + Isoproteuron) were applied at 25 DAS. Weed free plots were maintained by four hand weeding. Data were recorded on germination percentage (25 DAS), shoot length (cm) 15 & 30 DAS, root length (cm) 15 & 30 DAS, leaf chlorophyll content (ppm) at 25 & 30 DAS, dry weight (gm) at 30 DAS. Germination counted to 3 DAS, and it continued up to 25 DAS. The average leaf chlorophyll content was taken from five selected plants of each micro plot. Box plot presentation was done using Rstudio while Analysis of variance (ANOVA) was done with the help of Statistical Package for the Social Sciences (SPSS). The mean differences among the treatments were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez & Gomez 1984).

Result and Discussion

Plant population

In the box plot (Fig. 1) and Appendix 1, the rows indicate different treatments from (T_1-T_{18}) where the columns indicate the respective effect on plant population of those treatments. The box plot shows three different color shades where reddish shades indicate positive changes, purple shades indicate negative changes and light shades indicate near zero or neutral changes. Most treatments showed positive percentage changes in plant population with the highest positive change at 5.5% in treatment T_{10} (Pretilachlor fb Carfentrazone-ethyl) followed by T_4 (4.86%), T_3 (4.01%), T_{11} (3.98%). Treatment T_{18} with the most negative data set showed a significant negative percentage change in plant population (-11.28%) followed by the treatment T_1 (-1.59%). There was no significant change on plant population was noted for treatment T_6 (0.00%) with a negligible positive change for treatment T_5 (0.28%) and T_8 (0.53%).

The study reveals that application of most of the herbicides except T_{18} did not have any negative effect on germination and seedling establishment of jute. This result could be supported by Khokhar & Charak (2011) who found no residual effect of sulfosulfuron, Isoproteuon and Clodinofop on germination of maize, green gram and cucumber. Sangeetha et al. (2012) found no residual effect of Imazethapyr on the succeeding crops sunflower and pearl millet. The observation suggests that except for Triasulfuron and 2,4-D, the herbicides used during wheat cultivation do not have negative effect/impact on successful jute production. The causes of the variation are because of the chemical composition, rate of degradation and binding capacity with soil of individual herbicides. T_{10} helps to increase seed germination because of the minimum soil disturbance and fruitful weed prevention. For effective crop rotation and sustainable crop production with less residual toxicity, appropriate selection of herbicides is necessary.

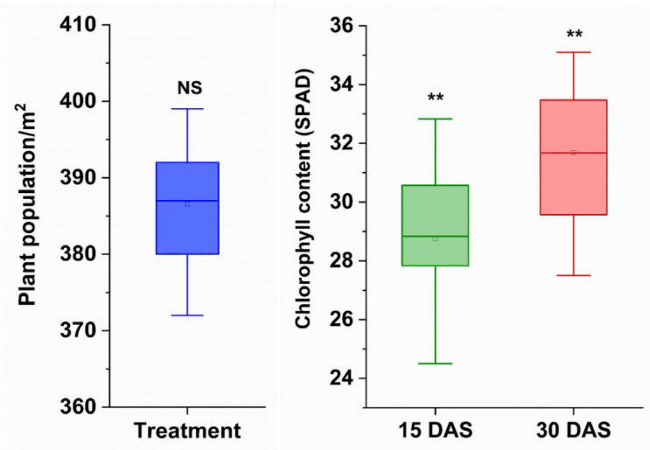

Fig. 1. Representing residual effects of herbicides on plant population and chlorophyll content of jute

Chlorophyll content of leaves (SPAD value)

In the box plot (Fig. 1) and Appendix 1, most treatments (T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13}, T_{14}, T_{15}, T_{16}, T_{17}, and T_{18}) are representing reddish shades (positive percentage changes) in SPAD value compared to the treatment T_2 (weed-free control) with the highest positive percentage changes for treatment T_6 (21.50%), T_{11} (15.70%) at 25 DAS and treatment T_2 (22.80%), T_3 (22.70%), at 50 DAS. These findings suggest that effective herbicide use not only controls weeds but also enhances the photosynthetic capacity of succeeding crops.

A very small percentage changes (light shades) in SPAD was noted for T_3 (1.18%), T_{12} (1.32%) at 25 DAS and T_1 (4.00%), T_5 (7.00%) at 50 DAS. Surprisingly, no negative changes (purple shades) were noted at 50 DAS where 3.50% and 4.70% was noted for T_{18} and T_1, respectively at 25 DAS. This reduction in T_1 highlights the adverse effects of weed competition on SPAD value (chlorophyll content of leaves).

Shoot length

In the box plot (Fig. 2) and Appendix 2 at 15 DAS, most treatment exhibited positive percentage changes (orange or red shades) in shoot length with the highest for treatment T_6 (28.4%) followed by T_6 (23.3%) and T_{10} (18.4%). Treatment T_3 and T_4 showed no changes (lighter shades) in shoot length and negative percentage changes for treatment T_{18} (-1.8%), T_2 (-12.1%) and T_1 (-13.6%). At 30 DAS, treat T_{11} showed the highest (46.2%) enhancement in shoot length followed by T_6 (24.9%), T_{10} (28.4%) and T_{13} (20.7%). Again, treatment T_3 and T_4 remained neutral whereas treatment T_{18} showed the largest negative change (-9.6%). Here, 9.42% and 8.94% CV (Appendix 2) was observed at 15 and 30 DAS, respectively which indicate the moderate variability among the data and the obtained results were significant at 1% level of significance emphasizing the reliability of obtained differences between different treatments. Ziveh & Taghizadeh (2012) reported that the use of mesotrione + terbuthylazin + s-metalachlor (2.4 l ha^{-1}, post emergence) on seedling weight and plant height was not significantly influenced by herbicides residue. One possible reason could be the differences in field conditions, herbicide dosages, and herbicide groups.

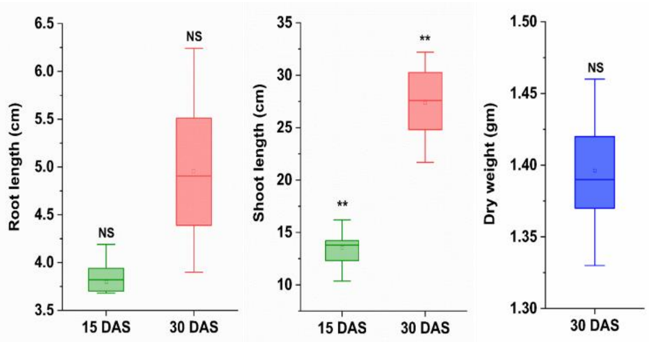

Fig. 2. Representing residual effects of herbicides on shoot length, root length and dry weight of jute

Root length

The root length of jute was statistically non-significant to the residual toxicity of herbicides used in the previous crops. Regarding root length, the box plot (Fig. 2) and Appendix 2 indicates nearly all the treatment showed positive percentage changes at 15 and 30 DAS including the highest positive change for T_{11} (56.0%). No significant negative changes were observed for root length at 30 DAS while treatment T_1 (-2.5%), T_2 (-2.5%) and T_{18} (-1.2%) showed certain negative changes at 15 DAS. Again, 8.57% and 11.58% CV (Appendix 2) at 15 DAS and 30 DAS mentioned a moderate variability among all the treatments and statistically non-significant (NS) indicate that the variation between all treatments might be because of random variation than actual treatment effects.

Dry weight

In the box plot (Fig. 2) and Appendix 2, the orange or red shades were more prominent at 30 DAS indicating a considerable positive change in dry weight for treatment T_{14} (24.0%), T_{13} (21.3%) and T_{11} (15.5%) compared to the treatment T_6 (6.7%), T_7 (6.7%) and T_{14} (8.2%) at 15 DAS. Blue shades remain consistent across both 15 and 30 DAS for treatment T_1 (-1.5%) and T_2 (1.5%), indicating their adverse effects on dry weight content of jute plants. On the other hand, 12.23% CV (Appendix 2) indicated moderate variability, whereas, non-significant (NS) indicated that difference among all the treatment because of random variation.

Correlation analysis between different traits at 30 DAS

The correlation between shoot length, root length, and dry weight at 30 DAS provide a significant relationship among the parameters (Table 1).

Table 1. Correlation between shoot length, root length and dry weight at 30 DAS (N = 18)

		Shoot length	Root length	Dry weigh
Shoot length	Pearson Correlation	1	0.682**	0.500*
	Sig. (2-tailed)		0.002	0.035
Root length	Pearson Correlation	0.682**	1	0.433
	Sig. (2-tailed)	0.002		0.073
Dry weight	Pearson Correlation	0.500*	0.433	1
	Sig. (2-tailed)	0.035	0.073	

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Particularly, shoot and root length were strongly correlated with each other (r = 0.682, p = 0.002), mentioned that plants which had long shoot tend to have longer roots. Again, shoot length and dry weight were moderately correlated which each other (r =

0.500, p = 0.035), indicated that long shoot plant had higher dry weight. Correlation between root length and dry weight (r = 0.433, p = 0.073) were not statistically significant. However, there was a positive relation between these variables. The results indicated that at 30 DAS, shoot length, root length, and dry weight were related with each other which could be applied to evaluate the growth and development of plant.

Conclusion

Data obtained from this study indicate that the residual effect of herbicides does not have a significant effect on plant population, root length, and dry weight of jute after strip tillage wheat cultivation, which reflects a minimal threat of herbicides on seed germination and root development of the succeeding jute crop. Also, this study establishes the feasibility of wheat-jute crop rotation, ensuring the development of the early phases of jute cultivation. A significant impact on shoot length and SPAD values has been reported, which indicates that herbicides may have an impact on chlorophyll synthesis and nutrient uptake of jute crops, whereas the shoot length variation expresses the possibility of affecting the above-ground growth of the plant. Above all, there was no impact of residual herbicide on the establishment of jute plants; however, it might have long-term negative effects on the growth and productivity of jute crops. Further study is needed for determining the impacts of shoot length and SPAD values on the production and fibre quality of jute. Also, future study should focus on residual impacts of herbicides on soil, including its interconnection with soil moisture, soil type, and nutrient availability. Research should be conducted to demonstrate the necessity of proper herbicide use management for sustainable crop production and securing the long-term potentiality of wheat-jute crop rotation for environmental and crop health safety net.

Competing Interest: The authors declare that they have no known competing financial interests.

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How to cite this article: Shamim MS, Rahman MM, Ahmed T & Haque MK (2025). Jute Response to Residual Herbicides in Strip-Tilled Wheat: Growth Challenges. Life Science Studies, 02(01), 18-24.

Appendix 1. Residual effect of herbicides on plant population and SPAD reading of jute

Treatment	Plant Population (m^{-2})	SPAD	
		25 DAS	30 DAS
T_1	372	24.50	27.50
T_2	378	25.40	28.87
T_3	395	29.90	33.40
T_4	385	31.15	33.63
T_5	379	29.10	31.68
T_6	378	30.87	33.57
T_7	390	28.27	31.13
T_8	380	28.10	29.87
T_9	387	27.83	29.57
T_{10}	399	26.63	29.50
T_{11}	393	30.57	33.47
T_{12}	383	28.42	31.27
T_{13}	392	29.40	33.10
T_{14}	396	25.70	29.27
T_{15}	389	29.13	32.73
T_{16}	385	31.17	34.90
T_{17}	391	28.57	31.67
T_{18}	324	32.83	35.10
CV (%)	11.70	7.13	5.63
Significance	NS	**	**
S_{x}^{-}	25.88	1.19	1.03

** Correlation is significant at the 0.01 level (Two-tailed test)

Appendix 2. Residual effect of herbicides on plant population and SPAD reading of jute

Treatment	Shoot length (cm)		Root length (cm)		Dry weight
	15 DAS	30 DAS	15 DAS	30 DAS	30 DAS
T_1	10.36	21.69	3.10	3.90	1.33
T_2	12.00	24.69	3.29	4.00	1.35
T_3	15.41	30.86	3.94	5.51	1.42
T_4	14.79	30.25	3.82	4.81	1.44
T_5	13.87	28.06	3.85	5.04	1.39
T_6	12.31	24.80	3.70	4.32	1.44
T_7	15.60	31.68	3.71	4.50	1.38
T_8	12.92	25.65	3.80	4.77	1.38
T_9	14.21	31.71	4.19	6.24	1.37
T_{10}	12.49	25.51	3.70	4.39	1.36
T_{11}	13.99	28.39	4.08	5.85	1.42
T_{12}	13.94	28.30	3.97	5.69	1.38
T_{13}	14.19	29.73	3.94	5.33	1.41
T_{14}	11.96	22.68	3.68	4.05	1.35
T_{15}	13.66	26.91	3.82	4.96	1.40
T_{16}	13.74	27.14	3.82	4.85	1.46
T_{17}	11.79	22.30	3.91	5.15	1.39
T_{18}	16.21	32.19	4.01	5.83	1.46
CV (%)	9.42	8.94	8.57	11.58	12.23
Significance	**	**	NS	NS	NS
S_{x}^{-}	0.74	1.41	0.19	0.33	0.09

** Correlation is significant at the 0.01 level (Two-tailed test)