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ORIGINAL ARTICLE

Role of seeding rate and variety in increasing yield performance and weed suppressing ability of wheat under strip tillage system

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Mechanical seeding of wheat under strip tillage system is time demanding technique that necessitates adjustment of the appropriate seeding rate for different wheat varieties to achieve optimum yield. However, high weed pressure is considered as a major cause of wheat yield loss in strip tillage system and hence an assessment needs to be carried out on integrated management approach to suppress weeds. Therefore, a study was conducted at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh during November 2012–March 2013 to examine the effect of seeding rate and variety on weed suppression and yield performance of wheat under strip tillage system. Three wheat varieties (BARI Gom-21, BARI Gom-24 and BARI Gom-26) were evaluated in the study with five seeding rates (40, 60, 80, 100 and 120 kg ha^{-1}) following a split-plot design with three replications. The study revealed that seeding rate and variety had significant effect on weed and yield of wheat under strip tillage system. Seeding at the rate of 120 kg ha^{-1} offered the highest weed suppression with the highest wheat yield. Among the varieties, BARI Gom-21 provided the superior performance on weed suppression and produced higher yield. The lowest grain and straw yields were obtained from BARI Gom-24 at 40 kg ha^{-1} seed rate with lowest weed suppression. The study concluded that mechanical seeding of BARI Gom-21 at the rate of 120 kg ha^{-1} was the best under strip tillage system that ensured maximum wheat yield with successful weed suppression.

INTRODUCTION

Wheat grown area of Bangladesh has remarkably increased in last 11 years (Parvez 2015) and at present, about 4.3 million hectare of land is under wheat cultivation (BBS 2016). Conventionally wheat is cultivated in a well prepared land with 3–4 heavy tillage resulted high cost of production. On the contrary, wheat cultivation with strip tillage (single pass shallow tillage) is becoming popular nowadays due to considering the environmental and economic advantages over conventional system (Baksh et al. 2014; Norberg 2010). Moreover, better wheat yield with higher economic return can be obtained under strip tillage system than conventional system (Hossain et al. 2014; Siddique 2004; Hossain et al. 2004). But, to date no research has documented about the mechanical seeding rate of wheat under strip tillage system in Bangladesh context.

High weed infestation is considered as a major barrier that can restrict the success of wheat cultivation under strip tillage system (Zahan et al. 2016). Weeds can be managed by manual or mechanical weeding or by using herbicides; however several earlier studies found increased seeding rate as an effective means of reducing the crop-weed competition (Xue and

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Stougaard 2002; Scursoni et al. 1999; Kirkland 1993). Blackshaw et al. (2000) reported that an increase in wheat seed rate from 50 to 300 kg ha^{-1} reduced red stem filaree (*Erodium cicutarium* L.) weed biomass by 53-95% over the years. In another study, Eslami et al. (2006) observed that growth and seed production of wild radish was adversely affected by increasing the density of wheat in Australia under no-tillage system. This might be happened due to high wheat plant coverage that helps to suppress weeds. It is also documented that increased crop competitiveness by using higher seeding rate can be an excellent possible technique for weed management (Lemerle et al. 2004). Previous researches find some wheat cultivars have potentiality to suppress weed because of their morphological traits (e.g., leaf inclination, extensive leaf display and shading ability, early vigor, rate of stem elongation and tiller number) that affect light interception and help to reduce crop-weed competition in wheat (Robert et al. 2001; Lemerle et al. 1996). Yenish and Young (2004) mentioned wheat height as major criteria of competitive cultivar that had consistent effect on weed and weed seed production, and they revealed taller wheat suppressed weed better than shorter wheat. Watson et al. (2006) also found a positive relationship between wheat heights at maturity and weed competitiveness. Additionally, optimum seeding rate and suitable cultivars play a vital role in achieving potential yield of wheat (Sikander et al. 2009; Khan 1996). Therefore, considering the above mentioned facts, the present study had taken to fulfill the following two objectives: (1) to examine the effect of seeding rate and variety on weed suppression and yield performance of wheat under strip tillage system and (2) to determine the best seeding rate and wheat variety for this system to achieve best possible yield.

MATERIALS AND METHODS

Experimental site and season

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh (24° 75′ N latitude and 90° 50′ E longitude at an altitude of 18 m above the sea level) during November 2012 to March 2013. The experimental site was a medium high land with sandy clay loam soil (50% sand, 23.4% silt, 26.6% clay) having pH 7.1 and moderate fertility having 1.65% organic matter content. Weather information regarding air and soil temperature, rainfall and relative humidity prevailed at the experimental site during the study period is presented in Table 1.

Table 1. Monthly record of air temperature, soil temperature, rainfall and relative humidity of the experimental site during November 2012 to March 2013

Months	Average air temperature (°C)			Average soil temperature (°C)			Total rainfall (mm)	Average relative humidity (%)
	Max.	Min.	Mean	5 cm	10 cm	20 cm		
November, 2012	28.4	16.9	22.7	24.3	25.0	25.5	18.9	81.7
December, 2012	22.9	13.2	18.0	20.4	20.7	21.2	0.0	88.9
January, 2013	23.8	10.6	17.3	17.7	18.2	18.6	0.0	78.7
February, 2013	28.3	15.8	22.1	21.4	21.9	22.1	1.2	71.2
March, 2013	31.9	19.6	25.6	26.3	26.7	26.4	21.0	73.9

Source: Weather Yard, Department of Irrigation and Water management, BAU, Mymensingh

Treatment and design

There were fifteen treatment combinations in the experiment where three (3) wheat varieties (BARI Gom-21, BARI Gom-24 and BARI Gom-26) and five seeding rates (120, 100, 80, 60 and 40 kg ha^{-1}) were evaluated. The experiment was set up in a split-plot design (variety was considered as main plot) with three replications. Unit plot size was 6 m × 3 m.

Methodology

In the experimental land, 20 cm residue of the previous crop, T. *aman* rice was retained during the time of harvest as per the norm of conservation agriculture systems. Before sowing wheat seeds, the existing weeds of the experimental land were killed by applying pre-planting non-selective herbicide glyphosate @ 3 L ha^{-1} on 14 November, 2012. The land was fertilized with phosphorus, potash and sulphur @ 30, 25 and 18 kg ha^{-1} in the form of TSP, MoP and Gypsum. Phosphorus and sulphur fertilizer were applied with Versatile Multi-crop Planter (VMP) at the time of seed sowing whereas potash fertilizer was applied by broadcasting. Seeds of three wheat varieties were sown within the 20 cm strip made by VMP on 20 November 2012 by maintaining seeding rate as per treatment requirement. Nitrogen fertilizer was applied @ 90 kg ha^{-1} into two instalments in the form of urea. First instalment of urea was applied at 15 days after sowing (DAS) and the second one was at the panicle initiation (PI) stage. At 3 and 25DAS, pre-emergence (Pendimethalin @ 3 L ha^{-1}) and post-emergence herbicide (2,4-D amine@ 1 L ha^{-1}) were applied, respectively in each plots to control weeds. Since no insect infestation was observed, no insecticide was applied in the experimental field.

Data recording and statistical analysis

Plant population was recorded at 15 DAS from the central 1 m^2 (1m × 1m) area. Weed samples were taken from randomly selected three spots of 0.25 m^2 (50 cm × 50 cm) areas at 50 DAS and weed population and dry matter were expressed in number m^{-2} and g m^{-2}, respectively . The crop was harvested at maturity on 21 March, 2013 from central 3 m^2 areas (3 m × 1 m) and the grain and straw yields were recorded. Grain yield was adjusted at 12% grain moisture level. Plant height and yield contributing characters such as number of tiller m^{-2}, number of spike m^{-2}, spike length, grains $spike^{-1}$ and 1000-grain weight were collected from randomly selected at five hills before harvest. The collected data were subjected to analysis of variance (ANOVA) and mean differences were compared by Least Significant Difference (LSD) Test using statistical package program ‘Statistical Tool for Agricultural Research (STAR) nebula’ developed by International Rice Research Institute (version 2.0.1, January 2014).

RESULTS AND DISCUSSION

Plant population

Wheat plant population (no. m^{-2}) at 15 DAS was significantly affected by seed rate, variety and their interaction (Table 2). Results showed that 120 kg ha^{-1} seeding rate gave the highest number of plants m^{-2} (106.4) and the lowest was found in 40 kg ha^{-1} seeding rate (33.6). Among the three varieties, BARI Gom-21 produced the highest number of plants m^{-2} (80.1) and the lowest number of plants m^{-2} (52.5) was obtained from BARI Gom-24. Consequently, interaction results also showed that the highest number of plants m^{-2} (121.3) was obtained from BARI Gom-21 at 120 kg ha^{-1} seeding rate whereas the lower (20.7) was counted from BARI Gom-24 at 40 kg ha^{-1}. The results clearly revealed that plant population of all of the varieties increased with increasing the seeding rate. Previous studies also confirmed that number of wheat plants per unit area increased with increasing seeding rate (Sharma and Singh 2011; Zecevic et al. 2014).

Table 2. Effect of seed rate and variety on plant population at 15 days after sowing of wheat under strip tillage system during 2012-13

Seed rate (kg ha^{-1})	**Variety**			**Mean**
	BARI Gom-21	BARI Gom-24	BARI Gom-26	
120	121.3 a	92.7 cd	105.3 b	106.4 A
100	101.3 bc	74.3 fg	91.0 de	88.9 B
80	72.7 gh	43.3 j	82.7 ef	66.2 C
60	64.0 hi	31.3 k	62.3 i	52.6 D
40	41.3 j	20.7 l	38.7 jk	33.6 E
Mean	80.1 A	52.5 C	76.0 B	
Level of significance	seed rate = ***, variety = ***, seed rate × variety = ***			
LSD value	seed rate = 5.06, variety = 3.92, seed rate × variety = 9.48			
CV (%)	8.08 for variety and seed rate, 8.09 for variety × seed rate			

Values having same letter(s) do not differ significantly whereas values with dissimilar letters differ significantly as per DMRT.
'CV' means 'co-efficient of variance', *** means 0.1% level of significance

Weed density and dry matter

Figure 1 showed that seed rate and variety had significant effect ($p<0.001$) on weed density and dry matter at 50 DAS of wheat. The lowest weed density (81 plants m^{-2}) and dry matter (11.1 g m^{-2}) were recorded from 120 kg ha^{-1} seeding rate while 40 kg ha^{-1} seeding rate had the highest weed density (211 plants m^{-2}) and dry matter (79.8 g m^{-2}). The results articulated that weed density and dry matter were successfully reduced by increased seeding rate of wheat. Similar result was reported by Lemerle et al. (2004); Scursoni et al. (1999); Kirkland (1993); Fischer and Ramirez (1993) that higher seeding rate increase the crop competitiveness as a result weeds were suppressed. In an experiment Xue and Stougaard (2002) found that biomass of wild oat was reduced by 20% when sowing rate of wheat was increased. Redstem filaree (*Erodium cicutarium* L.) weed biomass was also reduced by 53-95% over the years by increasing wheat seed rate from 50 to 300 kg ha^{-1} (Blackshaw et al., 2000). Furthermore, Eslami et al. (2006) reported that the growth and seed production of wild radish was adversely affected by increasing the density of wheat in a no-till system.

In case of variety, BARI Gom-26 had the lowest weed density (125 plants m^{-2}) and dry matter (39.0 g m^{-2}) while BARI Gom-24 had the highest weed density (151 plants m^{-2}) and dry matter (51.8 g m^{-2}). These differences may be appeared due to the variation in morphological traits of wheat varieties that affected light interception, space and nutrient availability resulted reduction in weed density and biomass (Lemerle et al. 1996; Roberts et al. 2001).

The interaction effect of seed rate and variety on weed density and dry matter was also found significant (Table 3). The lowest weed density at 50 DAS was recorded from BARI Gom-26 at 120 kg ha^{-1} seeding rate which was closely followed by BARI Gom-21 at 120 kg ha^{-1} seeding rate. However, BARI Gom-21 at 120 kg ha^{-1} seeding rate gave the lowest weed dry matter which was statistically followed by BARI Gom-26 at 120 kg ha^{-1} seeding rate. On the other hand, the highest weed density and dry matter were found from BARI Gom-24 at 40 kg ha^{-1} seeding rate and this happened due to the presence of less plant population which facilitated more weed emergence and establishment.

Yield and yield related attributes

Seed rate had significant effect on all the yield contributing characters (number of tillers m^{-2}, spikes m^{-2}, spike length, number of grains $spike^{-1}$, grain yield and straw yield) except 1000-grain weight (Table 4). Similar results were also reported by Kabir et al. (2009) that seeding rate had significant effect on yield and yield contributing characters except 1000-grain weight. The present study demonstrated that 120 kg ha^{-1} seeding rate produced the highest grain and straw yields (3.57 and 4.32 t ha^{-1}, respectively) because the highest number of tillers m^{-2} (278.2), spikes m^{-2} (270.0) and grains $spike^{-1}$ (45.9) were obtained from 120 kg ha^{-1} seeding rate. Whereas, 40 kg ha^{-1} seeding rate gave the lowest number of tillers m^{-2} (165.8), spikes m^{-2} (156.8) and grains $spike^{-1}$ (45.9) which resulted in the lowest grain and straw yields (2.00 and 2.81 t ha^{-1}, respectively). Sharma and Singh (2011) also found that variation in seed rate significantly influenced grain and straw yields of wheat and the highest grain and straw yields of wheat were obtained from 125 kg ha^{-1} seeding rate. Deshmukh et al. (2007) reported that wheat grain yield was significantly higher at 100 kg ha^{-1} seeding rate under bed planting system and it was at par with 75 kg ha^{-1} seeding rate. In contrast, Kiliç and Gürsoy (2010) and Mollah et al. (2009) reported that seed rate had no significant effect on grain yield of wheat in bed planting system.

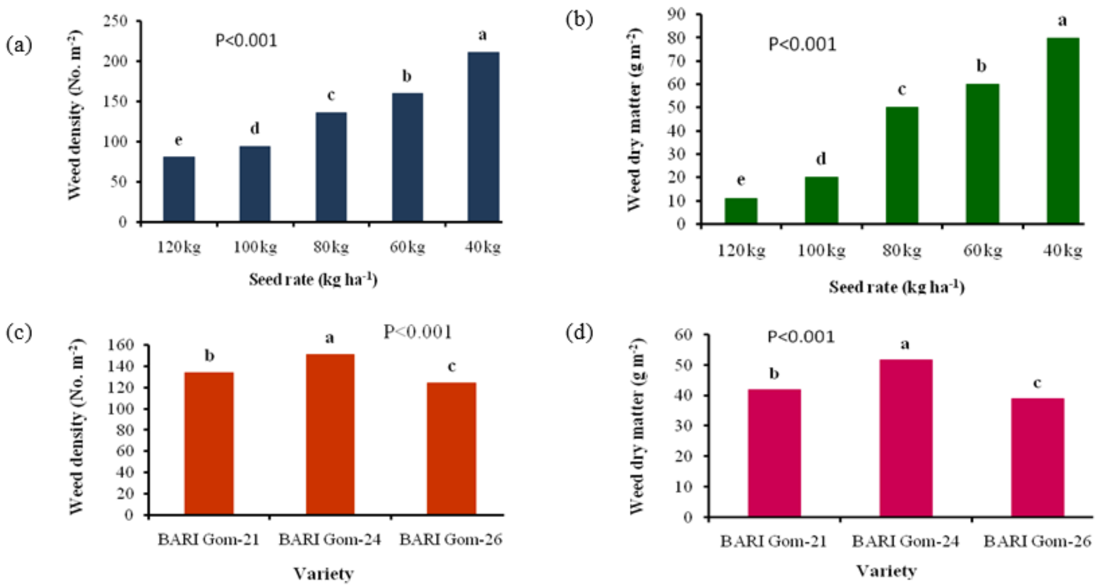

Figure 1. Effect of seed rate on (a) weed density and (b) dry matter and effect of variety on (c) weed density and (d) dry matter at 50 days after sowing of wheat under strip tillage system during 2012-13 (As per DMRT, bars with same letters do not differ significantly whereas bars with dissimilar letters differ significantly).

Table 3. Effect of seed rate and variety on weed density and dry matter at 50 days after sowing of wheat under strip tillage system during 2012-13

Seed rate × variety	**Weed density (No. m^{-2})**			**Weed dry matter (g m^{-2})**		
	BARI Gom-21	BARI Gom-24	BARI Gom-26	BARI Gom-21	BARI Gom-24	BARI Gom-26
120 kg ha^{-1}	70.7 h	102.3 fg	69.7 h	8.60 l	15.74 j	8.99 kl
100 kg ha^{-1}	88.0 gh	117.3 ef	76.7 h	13.03 jk	31.83 i	15.68 j
80 kg ha^{-1}	136.0 de	140.7 cd	132.7 de	49.67 g	55.55 f	44.91 h
60 kg ha^{-1}	162.0 bc	174.0 b	143.3 cd	60.44 e	67.74 d	52.21 fg
40 kg ha^{-1}	212.7 a	220.0 a	200.7 a	78.23 b	88.06 a	73.07 c
Level of significance		*			***	
LSD value		21.51			4.20	
CV (%)	4.32 for seed rate and variety, 6.95 for seed rate × variety			6.64 for seed rate and variety, 5.63 for seed rate × variety		

Values with same letter(s) do not differ significantly whereas values with dissimilar letters differ significantly.
'CV' means 'co-efficient of variance', *** means 0.1% level of significance, * means 5% level of significance

Table 4. Effect of seed rate on yield and yield contributing characters of wheat at harvest under strip tillage system during 2012-13

Seed rate (kg ha^{1})	**Number of tillers m^{-2}**	**Number of spikes m^{-2}**	**Spike length (cm)**	**Number of grains spike^{-1}**	**1000-grain weight (g)**	**Grain yield (t ha^{-1})**	**Straw yield (t ha^{-1})**
120	278.2 a	270.0 a	16.81 b	45.9 a	46.63	3.57 a	4.32 a
100	250.9 b	242.9 b	16.98 ab	44.4 ab	47.38	3.17 b	4.00 b
80	225.2 c	208.9 c	17.13 ab	42.6 abc	47.50	2.69 c	3.61 c
60	199.3 d	188.7 d	17.16 ab	41.5 bc	46.02	2.33 d	3.28 d
40	165.8 e	156.8 e	17.84 a	39.4 c	45.38	2.00 e	2.81 e
Level of sig.	***	***	*	***	ns	***	***
LSD value	7.66	11.88	0.88	3.53	-	0.26	0.23
CV (%)	2.50	4.10	4.58	5.43	3.40	7.97	6.92

In a column, values with same letters do not differ significantly whereas values with dissimilar letters differ significantly (as per DMRT at 5% level of significance).
CV = co-efficient of variance, * = 5% level of significance, *** = 0.1% level of significance, ns = not significant

Table 5 demonstrated that number of tillers m^{-2}, spikes m^{-2}, spike length, number of grains $spike^{-1}$, 1000-grain weight, grain yield and straw yield were significantly varied with wheat varieties. BARI Gom-21 produced the highest number of tillers m^{-2}, spikes m^{-2}, spike length and number of grains $spike^{-1}$ and BARI Gom-26 had the highest 1000-grain weight. Results revealed that the highest grain yield was provided by BARI Gom-21 which was closely followed by BARI Gom-26. In case of straw yield, the highest value was obtained from BARI Gom-21. On the other hand, BARI Gom-24 produced the lowest grain and straw yields because of having the lowest number of tillers and spikes m^{-2}.

Table 5. Effect of variety on yield and yield contributing characters of wheat at harvest under strip tillage system during 2012-13

Variety	**Number of tillers m^{-2}**	**Number of spikes m^{-2}**	**Spike length (cm)**	**Number of grains $spike^{-1}$**	**1000-grain weight (g)**	**Grain yield (t ha^{-1})**	**Straw yield (t ha^{-1})**
BARI Gom-21	257.9 a	244.3 a	17.87 a	46.4 a	45.33 b	2.96 a	4.40 a
BARI Gom-24	181.1 c	173.3 c	17.31 a	41.6 b	47.35 a	2.53 b	2.99 c
BARI Gom-26	232.7 b	222.7 b	16.38 b	40.3 b	47.07 a	2.77 a	3.42 b
Level of sig.	***	***	**	***	*	**	***
$LSD_{0.05}$	5.93	9.20	0.68	2.73	1.64	0.20	0.18
CV (%)	2.50	4.10	4.58	5.43	3.40	7.97	6.92

In a column, values with same letter(s) do not differ significantly whereas values with dissimilar letters differ significantly.
CV = co-efficient of variance, * =5% level of significance, ** = 1% level of significance, *** = 0.1% level of significance

On the other hand, the interaction effect of seed rate and variety on number of tillers and spikes m^{-2}, grain yield and straw yield was significant, but spike length, number grains $spike^{-1}$ and 1000-grain weight were non-significantly varied with treatments (Table 6). BARI Gom-21 produced the highest grain yield at 120 kg ha^{-1} seeding rate due to having the highest number of tillers and spikes m^{-2} and similar result also found in BARI Gom-26 at 120 kg ha^{-1}. In case of straw yield, the highest value was obtained from BARI Gom-21 at 120 kg ha^{-1} seeding rate which was closely followed by 100 kg ha^{-1} seeding rate of the same variety. On the contrary, 40 kg ha^{-1} seeding rate of BARI Gom-24 produced the lowest grain yield and straw yield because of producing the lowest number of tillers and spikes m^{-2}. The study also revealed that all the tested varieties gave their optimum yield at 120 kg ha^{-1} seed rate. Kabir et al. (2009) and Khan et al. (2009) also found similar results that the highest grain and straw yields were obtained from 140 kg ha^{-1} seed rate due to high plant population and less weed pressure and this was happened because with decreasing crop-weed competition more available resources were consumed by the crop.

Table 6. Interaction effect of seed rate and variety on yield and yield contributing characters of wheat under strip tillage system during 2012-13

Seed rate × variety		**Number of tillers m^{-2}**	**Number of spikes m^{-2}**	**Spike length (cm)**	**Number of grains $spike^{-1}$**	**1000-grain weight (g)**	**Grain yield (t ha^{-1})**	**Straw yield (t ha^{-1})**
BARI Gom-21	120 kg ha^{-1}	316.7 a	303.3 a	16.80	45.2	45.20	3.86 a	4.98 a
	100 kg ha^{-1}	288.7 b	282.7 b	16.93	43.9	45.57	3.47 bc	4.75 ab
	80 kg ha^{-1}	263.7 c	244.0 c	17.40	40.6	46.57	2.88 ef	4.55 b
	60 kg ha^{-1}	241.3 d	226.0 d	17.33	39.6	44.87	2.64 f	4.24 c
	40 kg ha^{-1}	179.3 ef	165.3 fg	18.07	38.6	44.43	2.05 g	3.49 ef
BARI Gom-24	120 kg ha^{-1}	226.0 d	221.3 d	17.37	48.5	47.33	3.11 de	3.84 d
	100 kg ha^{-1}	195.3 e	188.0 e	17.67	48.4	49.13	2.82 ef	3.54 ef
	80 kg ha^{-1}	188.0 e	174.7 ef	17.83	47.9	48.07	2.58 f	2.91 gh
	60 kg ha^{-1}	160.7 f	153.3 g	18.13	45.7	46.60	2.18 g	2.49 i
	40 kg ha^{-1}	135.3 g	129.3 h	18.33	41.5	45.60	1.93 g	2.18 j
BARI Gom-26	120 kg ha^{-1}	292.0 b	285.3 b	16.27	43.9	47.37	3.74 ab	4.15 c
	100 kg ha^{-1}	268.7 c	258.0 c	16.33	40.9	47.43	3.22 cd	3.70 de
	80 kg ha^{-1}	224.0 d	208.0 d	16.17	39.3	47.87	2.60 f	3.38 f
	60 kg ha^{-1}	196.0 e	186.7 e	16.00	39.1	46.60	2.15 g	3.10 g
	40 kg ha^{-1}	182.7 e	175.7 ef	17.13	38.1	46.10	2.03 g	2.76 h
Level of significance		*	***	ns	ns	ns	***	*
$LSD_{0.05}$		19.36	17.53	-	-	-	0.30	0.09
CV (%)		5.13	4.87	3.74	4.68	3.03	6.42	4.50

In a column, values with same letter(s) do not differ significantly whereas values with dissimilar letters differ significantly (as per DMRT at 5% level of significance).
CV = co-efficient of variance, * = 5% level of significant, *** =0.1% level of significant, ns = not significant

CONCLUSIONS

Seeding rate and variety had significant effect on weed and yield of wheat under strip tillage system. Seeding of wheat at 120 kg ha^{-1} exerted the highest weed suppression whereas BARI Gom-21 and BARI Gom-26 showed higher potentiality to suppress weeds under this system. Moreover, increased seeding rate provided the highest yield with the variety of BARI Gom-21. The performance of BARI Gom-26 was also satisfactory in term of grain yield while BARI Gom-24 performed worst under this system. The study concluded that cultivation of BARI Gom-21 at 120 kg ha^{-1} seeding rate is the best for better weed suppression and maximum wheat yield under strip tillage system.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

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