Journal of Food and Agricultural Technology Research
https://globalpresspk.com/
ISSN: 3007-0953 (Online)
ISSN: 3007-0945 (Print)

Weeds Dynamics as Influenced by Seeding Rates and Row Spacing in Winter Wheat

Fareeha Nasrullah [a], Maliha Naz [a], Umais Asghar Khan [b], Adnan Kashif [c], Sadam Hussain [d]*
[a] Department of Botany, University of Agriculture, Faisalabad, Pakistan
[b] Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan
[c] Department of Plant Pathology, University of Agriculture, Faisalabad, Pakistan
[d] College of Agronomy, Northwest A&F University, Yangling, China
***Corresponding author:** ch.sadam423@gmail.com

Abstract: Weeds are among the major yield-limiting factors for the wheat crop, which is a prominent cereal crop that provides a good source of carbohydrates and proteins for humans. However, under field conditions, wheat yield is severely affected by weed infestation. The present study was conducted to reduce weed infestation by optimizing the seeding rates and row spacing in winter wheat. A field study was conducted in 2019-20 where three-row spacing: 22.5 cm (RS1), 17.5 cm (RS2), and 11.5 cm (RS3), and three seeding rates: 125 kg ha^{-1} (SR1), 150 kg ha-1 (SR2) and 175 kg ha-1 (SR3) were tested. Our results showed that the highest weed density and biomass production were recorded under SR1 and RS1 treatments. However, SR3 and RS3 depicted minimum weed density and dry weights in this experiment. Similarly, the plots with greater row spacing produced more grain yield as compared to narrowly spaced rows maximum grain yield (4.68 t ha^{-1}) was depicted for RS1 and SR2. In conclusion, RS1 and SR1 treatments were more effective in reducing the weeds' densities and increasing crop productivity.
Keywords: Row spacing, wheat crop, Seeding rates, Weeds

Article History
Received: 24 March 2022; Revised: 01 August 2022; Accepted: 22 August 2022
Online: 27 September 2022; Published: Volume (1) Issue (1) December 2022
https://doi.org/10.69501/1a86fg30

1. Introduction

Wheat (*Triticum aestivum* L.), an important member of the family Poaceae, is one of the most prominent cereals and staple food in many countries including Pakistan. It is estimated that the wheat crop is cultivated on about 20% of arable land on the globe (Cao *et al*., 2017). Wheat grains provide a good source of carbohydrates and proteins in the human diet. The wheat crop also plays a vital role in the stability of the economic condition of the country. Globally, Pakistan is ranked 8th and 6th in terms of wheat cultivated area and production, respectively (FAOSTAT, 2009).

Weeds infestation is a major restriction to wheat production (Zimdahl, 2013; De Vita *et al*., 2017). The productivity and quality of wheat are directly influenced by weed-crop competition; weeds compete for water, light, and nutrient resources, and act as a host for many insects and pests (Zimdahl, 2013). The major influx of weeds comprises *Cronopus didymus* (CDI), *Convolvulus arvensis* (CAR), *Chenopodium album* (CAL), and *Phalaris minor* (PM) (Usman *et al*., 2016, 2020). Weeds are responsible for about 13-38% and 25-47% losses in average straw and grain yield, respectively in wheat crops (Iqbal *et al*., 2018; Manandar *et al*., 2007). Weeds are commonly controlled by the application of weedicides, such as pre-emergence and post-emergence applications; however, these methods are not fully effective to control weeds (Berti *et al*., 2016; Donovan, 2013). On the other hand, excessive use of chemicals including herbicides also induces herbicides-resistance (Norsworthy *et al*., 2012), reduces soil microbial communities, and impacts the environment and ecosystem sustainability (Aubertot *et al*., 2007; Boily *et al*., 2013; Santadino *et al*., 2014; Portier *et al*., 2016). Therefore, integrated weed management approaches should be adopted to control weeds and encounter the above-mentioned impacts in large-scale agricultural systems (Bajwa *et al*., 2015). In this regard, changing planting geometry may provide a sustainable solution to reduce weed population dynamics while protecting the soil environment.

Agronomic management practices including crop competitiveness to control weeds and changing planting geometry are the most pragmatic cultural-weed-management approaches worldwide, which suppress the weed density and biomass, and lead to improvement in crop productivity (Lemerle *et al*., 2004; Scott *et al*., 2013; Sardana *et al*., 2017). These approaches significantly facilitate the crop to capture more sunlight to grow better and restrict the available resources for weed plants to suppress their growth (Weiner *et al*., 2001). Among these, increasing the seeding rate has remarkably been affirmed to increase the crop competitiveness in many kinds of cereals crops such as wheat, rice (*Oryza sativa*), and barley (*Hordeum vulgare*) over diverse weed flora (Borger *et al*., 2016a; Li *et al*., 2018). According to Peltzer (1999), higher seeding rates impacted the growth and diversity of different weeds which in turn increased the crop yield. Another option comprises is to introduce or change the intra-specific row spacing (i.e., wider, or narrow row arrangement) has admirably been proven in managing weed populations in many countries (Scott *et al*., 2013; Lemerle *et al.,* 2004, 2013; Drews *et al*., 2009; Solie *et al*., 1991). In this regard, Fahad *et al*. (2015) stated that low row spacing potentially suppressed the growth and abundance of many weed species, including the most abundantly existed family *Avena fatua*. However, there are contradictive reports on row spacing as some researchers also reported that increased sowing rate and reduced row spacing facilitate weed growth (Hu *et al*., 2015; Boström *et al*., 2012; Chen *et al*., 2008; Roberts *et al*., 2001). It is commonly known that optimal row spacing and seeding rates provide better solar radiation interception, early canopy architecture, better utilization of water and nutrients, and ultimately improve wheat-yielding and suppress the growth of weeds. Thus, this is imperative to design/allocate suitable row spacing along with an appropriate seeding rate to encourage the wheat yield and reduce the weed population dynamics. In this study, we hypothesized that narrowly spaced crop rows coupled with high seed rates would beneficial for suppressing the weeds' densities and improving wheat yield. Our major objective in this work was to examine the effect of different row spacing and seeding rates on weeds densities, biomass production, and productivity of the wheat crop.

2.Materials and Methods

2.1. Experimental site

This field study was performed in 2019-20 at the Agronomic Research Area. The physicochemical properties of the experimental soil were analyzed by using the protocol of Estefan et al. (2013). The soil of the experimental site was sandy loam in nature and contains; 48.5% sand, 31.8% silt, 21% clay, soil saturation percentage (SSP) 27%, organic matter (O.M) 0.70%, pH 7.9, electrical conductivity (EC) 1.85 dS m^{-1}, total nitrogen-N 0.05%, available phosphorus contents-P 5.6 ppm, and exchangeable potassium contents-K 115 ppm. The weather data including maximum/minimum temperatures, relative humidity, and monthly rainfall, during the crop period, were obtained from the metrological observatory cell, and presented in (Table 1).

Table 1. Monthly means maximum (oC, T. maximum) and minimum temperature (T. minimum), relative humidity, and total rainfall (mm) during the wheat growth period

	T. maximum	T. minimum	Humidity (%)	Total rainfall (mm)
November	27.0	12.4	75.06	1.5
December	21.7	06.5	82.05	4.2
January	19.2	07.0	80.5	00
February	20.3	09.1	78.5	9.5
March	26.0	13.8	63.5	12.5
April	35.0	20.6	60.5	7.9

2.2. Experimental design and treatments

In this work, each treatment was repeated three times and arranged under a randomized complete block design (RCBD) with a split-plot arrangement. Each experiment plot had a 1.8 m × 5 m area. The experimental treatments comprised of three-row spacing (RS_1= 22.5 cm, RS_2= 17.5 cm, RS_3= 11.5 cm) plots and three diverse seeding rate (SR_1= 125 kg ha^{-1}, SR_2= 150 kg ha^{-1}, SR_3= 175 kg ha^{-1}).

2.3. Crop husbandry

Seeds of wheat cultivar Ujala-2016, a commonly used cultivar in the study area, were procured from Wheat Research Institute, Faisalabad. The experimental plots were cultivated two times with the help of tractor driven cultivator accompanied by heavy planking and leveling each time. The crop was sown on November 23, 2019, by using a simple hand drill and maintaining row to row distance and seeding rate according to experimental treatments. Based on soil analysis, which was taken before sowing of the crop, fertilizers such as N, P, and K were supplemented at 100, 90, and 75 kg ha^{-1} respectively from urea (N 46%), DAP (P 46%, N 18%), and SOP (K_2O, 50%). One-third of N and the whole amount of P and K were applied as a basal application at the time of seedbed preparation while the remaining N was supplemented in two equal doses at 1st irrigation (20 DAS; days after sowing) and 2nd irrigation (55 DAS). In the current study, four irrigations were applied during the whole growing season each year. The crop was harvested on April 30, 2020.

2.4. Observations

2.4.1. Weeds density

Weeds density at 40, 60, and 80 days after sowing (DAS) were identified and counted from each plot by using a 1 m^2 rectangular quadrate. The individual weeds populations were counted manually, and the average thereafter.

2.4.2. Weeds dry biomass determination

Weeds were sampled at 40, 60, and 80 DAS respectively from each plot by using a 1 m^2 rectangular quadrate. To ascertain the dry biomass, these samples were placed in an oven at 65°C till constant weight. Later, these samples were weighed on a digital weighing balance to record the dry biomass of individual weed species.

2.4.3. Grain yield attributes

At harvesting, three subsamples for 1000-grain weight were procured from each treated plot and weighed on a digital balance, and then averaged. To determine the biological yield, each plot was harvested, knotted into a bundle, remain in the field for one week to dry, and then weighed the complete harvested material on a digital weighing balance. After that threshing was done by using a mini-thresher and separating straw and grains, and then grain yield was recorded at 13% moisture content approximately.

2.5. Statistical analysis

Recorded data on weed densities, biomass, crop growth, and yield parameters were analyzed through the fisher's analysis of variance technique. The least significant difference (LSD) test at 5% was applied to compare the differences among treatment means by using the statistical package DSAASTAT (Ver. 1.02) (Steel *et al*., 1997). The figure was drawn using Sigma plot software.

3.Results and discussions

3.1. Weed densities and biomass at 40 DAS

In this study, we evaluated the weed densities and biomass of four commonly existed species such as *Convolvulus arvensis, Chenopodium album, Phalaris minor,* and *Avena fatua*. Data showed that seed rates, row spacing, and their interactions significantly affected the weed's densities and biomass production 40 days after sowing (Table 2). The maximum values for weed density were observed in the plot treated with a seeding rate and row spacing of 125 kg ha^{-1} and 22.5 cm, respectively. While SR_3 treatment where seeds were applied at 175 kg ha^{-1} and RS_1 treatment with row spacing of 22.5 cm gave the highest weed biomass of all tested weed species. The minimum weed density and dry weights were recorded in SR_3 treatment comprising a seeding rate of 175 kg ha^{-1} and RS_3 treatment comprising row spacing of 11.5 cm in all weed species (Table 2).

3.2. Weed densities and biomass at 60 DAS

Row spacing, seeding rates, and their interaction significantly affected the weed density and biomass production of all weed species days after sowing. Our data showed that the lowest increment in weed densities, as well as weed biomass production, were depicted in SR_1 treatment in which seed was applied at the rate of 125 kg ha^{-1} and RS_3 comprising row spacing of 11.5 cm in all species. However, the highest weed densities and biomass production of all weed species were observed in the plots in which wheat seeds were sowing at the rate of 175 kg ha^{-1} (SR_3) and row spacing of 22.5 cm (RS_1) (Table 3).

Table 2: Effect of row spacing and seed rates on weed density (DEN), and dry weights (DW) at 40 days after sowing

Row spacing	Seed rates (kg ha^{-1})	Convolvulus arvensis		Chenopodium album		Phalaris minor		Avena fatua	
		DEN	DW	DEN	DW	DEN	DW	DEN	DW
22.5	125	30.13 bc	13.66 cd	28.22 ab	7.44 b-e	9.33 c-e	20.90 a-e	28.66 a	39.50 bc
	150	31.93 bc	16.33 bc	29.76 a	7.84 a-e	10.60 a-d	25.33 a	29.82 a	51.10 ab
	175	49.70 a	24.27 a	30.00 a	9.34 ab	13.53 a	25.67 a	27.83 a	51.22 ab
17.5	125	26.33 cd	9.93 d-g	20.78 b-d	6.50 c-f	8.89 c-e	17.50 c-f	10.66 bc	14.13 f
	150	27.03 b-d	10.46 d-g	28.77 a	6.80 c-f	9.76 b-e	17.45 c-f	24.76 a	28.74 cd
	175	28.67 bc	11.65 d-f	29.10 a	7.83 a-e	13.09 ab	22.70 a-c	24.40 a	33.13 c
11.5	125	15.80 e	4.91 h	11.26 e	5.46 ef	9.37 c-e	3.50 i	8.76 c	7.00 f
	150	21.20 de	7.00 gh	17.77 de	6.36 e-f	6.83 e	11.35 gh	9.77 c	10.33 f
	175	29.10 bc	11.16 d-f	27.20 ab	7.13 b-e	9.83 b-e	23.20 ab	14.73 bc	18.03 d-f

Analysis of variance

	C. arvensis		C. album		Phalaris minor		Avena fatua	
Row spacing (RS)	**	**	**	**	**	**	**	**
Seed rates (SR)	**	**	**	**	**	**	**	**
RS × SR	**	**	**	ns	**	**	**	**

Means within a column followed by the same letter(s) are not significantly different (ns) at P>0.05 based on Duncan's Multiple Range Test. P-value indicates significance level based on two-way ANOVA. **P≤0.01

Table 3: Effect of row spacing (RS) and seed rates (SR) on weed density (DEN), and dry weights (DW) at 60 days after sowing

RS	SR (kg ha^{-1})	Convolvulus arvensis		Chenopodium album		Phalaris minor		Avena fatua	
		DEN	DW	DEN	DW	DEN	DW	DEN	DW
22.5	125	53.90 g-i	31.83 ef	35.76 b-d	21.13 a-c	19.26 c-e	39.66 de	25.90 ab	17.13 a-e
	150	65.10 b-e	42.40 b-d	36.40 a-c	20.53 a-c	22.83 a-c	48.47 ab	31.53 a	21.93 a
	175	75.47 ab	51.13 ab	41.16 a	24.03 a	25.73 a	51.16 a	33.50 a	22.86 a
17.5	125	42.96 g-i	21.20 g	26.16 g-i	14.23 d-f	19.40 c-e	35.83 ef	12.76 de	9.93 e-g
	150	56.20 e-g	35.30 de	29.43 f-h	17.33 b-e	21.07 b-d	39.83 de	21.10 b-d	13.93 b-g
	175	64.30 c-f	44.00 b-d	30.97 d-g	16.80 c-e	22.10 b-d	45.13 bc	27.63 ab	19.43 a-c
11.5	125	23.83 j	9.94 h	14.40 k	7.36 g	13.87 gh	26.46 g	9.13 e	7.40 g
	150	39.17 i	22.93 g	20.73 j	11.03 fg	15.55 f-g	28.66 g	9.90 e	8.36 fg
	175	47.93 g-i	27.16 e-g	27.00 f-i	13.67 d-f	18.80 ef	36.89 ef	15.36 c-e	11.90 c-g
Analysis of variance									
		C. arvensis		C. album		Phalaris minor		Avena fatua	
Row spacing (RS)		**	**	**	**	**	**	**	**
Seed rates (SR)		**	**	**	**	**	**	**	**
RS × SR		ns	ns	**	*	*	**	**	ns

Means within a column followed by the same letter(s) are not significantly different (ns) at P>0.05 based on Duncan's Multiple Range Test. P-value indicates significance level based on two-way ANOVA. *P≤0.05, **P≤0.01

3.3. Weed densities and biomass at 80 DAS

There was a significant difference in weed dry weights and weed densities at 80 DAS among the treatments and their interactions. Data showed that the lowest weed densities and biomass production were recorded in treatment in which wheat seeds were sown at the rate of 125 kg ha^{-1} (SR_1) and RS_3 treatment with row spacing of 11.5 cm for all weed species. However, the highest weed densities and biomass production of all species were observed in the plot where wheat seeds were sown at the rate of 175 kg ha^{-1} and row spacing of 22.5 cm (Table 4).

Table 4: Effect of row spacing and seed rates (SR) on weed density (DEN), and dry weights (DW) at 80 days after sowing

Row spacing	SR (kg ha^{-1})	Convolvulus arvensis		Chenopodium album		Phalaris minor		Avena fatua	
22.5	125	31.10 a-f	16.00 a-d	40.73 a-c	21.33 a-d	20.66 a-d	44.50 a-f	28.16 a-c	29.56 a-c
	150	33.70 a-d	18.63 a-c	41.63 a-c	23.16 ab	21.93 a-c	47.06 a-d	35.43 a	36.63 a
	175	38.46 ab	20.56 a	43.66 a	24.26 a	24.43 ab	54.43 ab	36.23 a	38.13 a
17.5	125	23.93 d-g	11.53 de	32.43 b-e	18.60 a-d	19.10 a-e	41.66 a-f	14.40 ef	15.16 ef
	150	32.66 a-e	17.36 a-d	34.30 a-e	18.66 a-d	21.63 a-c	46.36 a-d	25.16 b-d	26.23 b-d
	175	33.76 a-d	17.60 a-d	38.66 a-d	21.93 a-c	23.03 a-c	48.36 a-d	29.43 a-c	30.60 a-c
11.5	125	19.93 g	9.16 e	19.13 gh	9.76 f	12.40 e	27.06 f	11.73 f	13.40 f
	150	22.05 e-g	11.56 de	21.00 f-h	10.23 ef	15.76 c-e	33.46 d-f	11.40 f	12.43 f
	175	27.60 c-g	13.06 c-e	28.60 d-g	17.33 b-d	18.00 b-e	38.23 b-f	17.10 d-f	19.00 d-f
Analysis of variance									
		C. arvensis		C. album		Phalaris minor		Avena fatua	
Row spacing (RS)		**	**	**	**	**	**	**	**
Seed rates (SR)		**	**	**	**	**	**	**	**
RS × SR		ns	ns	ns	*	ns	ns	**	**

Means within a column followed by the same letter(s) are not significantly different (ns) at $P>0.05$ based on Duncan's Multiple Range Test. P-value indicates significance level based on two-way ANOVA. $*P \leqslant 0.05$, $**P \leqslant 0.01$

3.4. Total weeds dry biomass

Our data depicted a significant influence of treatments (row spacing and seeding rates) and their interaction on total weed biomass and densities of all weed species. Where the lowest biomass of weeds and weed densities were recorded for plots treated with row spacing of 11.5 cm and SR_1 treatment in which seeds were sown with the rate of 125 kg ha^{-1}. Meanwhile, the maximum total biomass of weeds and densities were obtained for SR_3 treatment with a seeding rate of 175 kg ha^{-1} and RS_1 treatment with row spacing of 22.5 cm (Table 5).

Table 5: Effect of row spacing and seed rates on total weed biomass at 40, 60, and 80 days after sowing

Row spacing	**Seed rates (kg ha^{-1})**	**Total biomass dry biomass**		
		40 DAS	**60 DAS**	**80 DAS**
22.5	125	48.27 c	80.25 c	100.98 c
	150	51.54 b	92.01 b	111.81 b
	175	89.37 a	126.23 a	152.23 a
17.5	125	41.66 e	64.75 e	85.92 d
	150	41.81 e	70.17 d	86.81 d
	175	48.27 c	79.34 c	99.36 c
11.5	125	9.72 g	34.55 g	51.43 f
	150	30.30 f	58.71 f	76.64 e
	175	45.69 d	69.97 d	87.39 d
Analysis of variance				
Row spacing (RS)	**	**	**	
Seed rates (SR)	**	**	**	
RS × SR	**	**	**	

Means within a column followed by the same letter(s) are not significantly different (ns) at P>0.05 based on Duncan's Multiple Range Test. P-value indicates significance level based on two-way ANOVA. **P≤0.01.

3.5. Yield and yield-related traits

In this work, wheat grain yield and 1000-grain weight were influenced significantly (P>0.01) by row spacing and seed rate, however, there was a non-significant effect on their interactions (Table 6). The plots with greater row spacing (RS_1 treatment) produced the highest grain yield as compared to others with less spacing. In this experiment, a maximum increment in grain yield (4.67 t ha^{-1}) was depicted for RS_2 and SR_1 treatments in which the plots were treated with a row spacing of 17.5 cm, and seeds were sown at the rate of 125 kg ha^{-1} (Table 6).

The treatments with narrow row spaces coupled with high seed rates were more imperative in decreasing the dry biomass of tested weeds, however, these caused a slight reduction in grain yield, which support our hypothesis. In this study, lower productivity of wheat crop and increased weed infestations were depicted in replicated plots treated with wider (22.5 cm) crop rows than the replicated plots which have narrow row spacing (11.5 cm). The above-mentioned findings could be described by the statement that broader rows, compared to narrow rows, have a corresponding canopy, permitting significant weed growth and resultant competition for row spacings could have permitted the crop to effectively manipulate the existing space and lessen the space accessible for weed growth. In addition, consistent allocation of crop plants planted in narrow rows might have followed ineffective usage of existing resources for plants such as essential nutrients, light, and moisture by crop plants (Weiner *et al.*, 2001, Acciaresi and Chidichimo, 2007; Ashraf *et al.*, 2014).

Table 6: Effect of row spacing and seed rates on 1000-grain weight, biological yield, grain yield of wheat

Row spacing	Seed rates (kg ha^{-1})	1000-grain weight (g)	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})
11.5	125	39.46 b-f	11.07	3.77
	150	38.43 c-f	11.27	3.53
	175	37.50 ef	11.66	3.73
17.5	125	41.73 a-f	9.63	4.67
	150	41.23 a-f	10.66	4.50
	175	40.00 a-f	10.73	3.60
22.5	125	42.76 a-d	9.26	4.43
	150	44.83 a	9.93	4.30
	175	42.16 a-e	11.10	3.77
Analysis of variance				
		1000-grain weight	Biological yield	Grain yield
Row spacing (RS)		**	ns	**
Seed rates (SR)		*	*	**
RS × SR		ns	ns	ns

Means within a column followed by the same letter(s) are not significantly different (ns) at P>0.05 based on Duncan's Multiple Range Test. P-value indicates significance level based on two-way ANOVA. *$P \leq 0.05$, **$P \leq 0.01$.

decreasing the seed yield. In distinction, sowing wheat with narrow Intended for, apart from interspecific as well as intraspecific interactions between crop plants and weeds, crop-weed competition for attaining the available resources may be manipulated by the weather conditions accomplished over the experiment, the allelopathic phenomenon under field, and the spatial as well as the temporal variations in the accessibility of available nutrients and other essential resources, including light and water. This complicated interaction between these factors can make it complicated to determine specific treatment effects, such as planting geometry i.e., row spacing and seeding rates on weeds as well as on crop-related traits (Harper, 1977; Lemerle *et al*., 2013). Expanded crop densities can lessen weed biomass both under the absence and application of N fertilizer, in experimental units where spring wheat experienced elevated weed growth (Kristensen *et al*., 2008). Moreover, Aldrich (1987) stated that high weed growth during early crop growth stages increased the yield losses. In addition, environmental conditions such as thermal environment, relative humidity, and availability of the resource can also affect the interactions between the crop plants and weeds species (Kropff *et al*., 1993, Guillemin *et al*., 2013).

4. Conclusion

In sum, our data have reported that row spacing and seeding rates in wheat not only affected the crop productivity but also the densities and biomass production of weeds at various competition periods. Overall, our results showed that SR_1 and RS_1 treatments depicted the highest weed densities and biomass production, and SR_3 and RS_3 recorded the minimum weed densities and dry weights. Also, the plots with greater row spacing produced more grain yield as compared to low row spacing where the highest grain yield was observed for RS_1 and SR_2 treatments.

Acknowledgment

We thank the worthy reviewers for their comments on improving the quality of the manuscript.

Declaration of competing interest

The authors have no conflict of interests to declare.

References

Acciaresi, H.A. and Chidichimo, H.O., 2007. Spatial pattern effect on corn (Zea mays) weeds competition in the humid Pampas of Argentina. International Journal of Pest Management, 53(3), pp.195-206.

Aldrich, R.J., 1987. Predicting crop yield reductions from weeds. Weed Technology, pp.199-206.

Ashraf, U., Anjum, S.A., Khan, I. and Tanveer, M., 2014. Planting geometry-induced alteration in weed infestation, growth and yield of puddled rice. Pakistan Journal of Weed Science Research, 20(1).

Banisaeidi, A.K., Zand, E., Modhj, A., Lak, S. and Baghestani, M.A., 2014. Effect of seeding rate and variety on wild oat (Avena ludoviciana L.) suppression and yield of spring wheat (Triticum aestivum L.). International Journal of Biosciences (IJB), 5(12), pp.166-172.

Borger, C.P.D., Riethmuller, G. and D'Antuono, M., 2016. Eleven years of integrated weed management: long-term impacts of row spacing and harvest weed seed destruction on Lolium rigidum control. Weed Research, 56(5), pp.359-366.

Boström, U., Anderson, L.E. and Wallenhammar, A.C., 2012. Seed distance in relation to row distance: Effect on grain yield and weed biomass in organically grown winter wheat, spring wheat and spring oats. Field Crops Research, 134, pp.144-152.

Drews, S., Neuhoff, D. and Köpke, U., 2009. Weed suppression ability of three winter wheat varieties at different row spacing under organic farming conditions. Weed Research, 49(5), pp.526-533.

Fahad, S., Hussain, S., Chauhan, B.S., Saud, S., Wu, C., Hassan, S., Tanveer, M., Jan, A. and Huang, J., 2015. Weed growth and crop yield loss in wheat as influenced by row spacing and weed emergence times. Crop Protection, 71, pp.101-108.

Guillemin, J.P., Gardarin, A., Granger, S., Reibel, C., Munier-Jolain, N. and Colbach, N., 2013. Assessing potential germination period of weeds with base temperatures and base water potentials. Weed Research, 53(1), pp.76-87.

Harper, J.L., 1977. Population biology of plants. Population biology of plants.

Koscelny, J.A., Peeper, T.F., Solie, J.B. and Solomon Jr, S.G., 1990. Effect of wheat (Triticum aestivum) row spacing, seeding rate, and cultivar on yield loss from cheat (Bromus secalinus). Weed Technology, pp.487-492.

Kristensen, L., Olsen, J. and Weiner, J., 2008. Crop density, sowing pattern, and nitrogen fertilization effects on weed suppression and yield in spring wheat. Weed Science, 56(1), pp.97-102.

Kropff, M.J., 1993. The impact of environmental and genetic factors. Modelling crop-weed interactions, pp.137-147.

Kühling, I., Redozubov, D., Broll, G. and Trautz, D., 2017. Impact of tillage, seeding rate and seeding depth on soil moisture and dryland spring wheat yield in Western Siberia. Soil and Tillage Research, 170, pp.43-52.

Lemerle, D., Lockley, P., Koetz, E. and Diffey, S., 2013. Herbicide efficacy for control of annual ryegrass (Lolium rigidum Gaud.) is influenced more by wheat seeding rate than row spacing. Crop and Pasture Science, 64(7), pp.708-715.

Olsen, J., Kristensen, L. and Weiner, J., 2005. Effects of density and spatial pattern of winter wheat on suppression of different weed species. Weed Science, 53(5), pp.690-694.

Weiner, J., Griepentrog, H.W. and Kristensen, L., 2001. Suppression of weeds by spring wheat Triticum aestivum increases with crop density and spatial uniformity. Journal of Applied Ecology, pp.784-790.