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Effect of different herbicides on growth, yield and economics of crops in wheat-chickpea intercropping system

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Abstract
In the *Rabi* season of 2020–2021, a field experiment was carried out at the Lovely Professional University's School of Agriculture in Phagwara, Punjab. The eight treatments in the field experiment were Pendimethalin 1000 ml/ha (PE), Isoproturon 1000 g/ha (PoE), Cladinofop-propargyl 60 g/ha (PoE), Pinoxaden 50 g/ha (PoE), Hand weeding at 60 DAS, Metribuzin 250 g/ha (PE), Weedy Check, and Weed free check. There were eight treatments total: one weedy check, one weed free check, five chemical treatments, and one hand weeding. A 2:1 ratio of wheat to chickpeas was used, with a row-to-row spacing of 30 cm. The largest growth parameters for both wheat and chickpea crops (plant height, dry matter accumulation per plant, chlorophyll index, number of tillers per running meter, CGR, and RGR) as well as the characters that contribute to yield (number of spikelets per spike, spike length, effective tillers per running meter, number of grains per spike, test weight, number of pods per plant, primary and secondary branches, seed index) were found in the treatments of pendimethalin 1000 ml/ha (PE). The wheat crop experienced growth, development, and yield reductions as a result of certain phytotoxic symptoms of metribuzin 250 g/ha (PE). The application of 1000 ml/ha (PE) of pendimethalin also showed the highest harvest index, grain yield, straw yield, and B:C ratio.

Keywords: Herbicide, growth, yield, B: C ratio, phyto toxicity

Introduction
Wheat (*Triticum aestivum* L.) is a cereal crop that belongs to the family "Graminae" and the genus "Triticum." Wheat is the world's most frequently grown and important cereal crop, ranking first in both area and production among cereal crops. Wheat is a nutrient-dense food that is used to make bread, cakes, bakeries, flakes, biscuits, and alcohol, among other things, and is mostly consumed in India as chapaties. Despite the fact that the population has doubled since 1961, wheat availability has increased from roughly 79 g capita^{-1} day^{-1} to more than 185 g capita^{-1} day^{-1}. Chickpea or gram (*Cicer arietinum*) is a significant semi-arid tropics pulse crop, notably in the Indian subcontinent's rainfed ecosystem. The daily availability of 14g chickpea provides roughly 2.3 percent (56 kcal) calories and 4.7 percent (2.7 g) protein to the Indian population, in addition to being a good source of calcium and iron (10-12%).
Due to its potential benefits over yields, better utilization of growing resources by various crops, and increased consistency from season to season, intercropping has piqued interest recently. Direct nitrogen transfer from the legume to the cereal crop during intercropping, which is most typically done with cereals, may enhance the nitrogen nutrition and nitrogen fixation of the partnered crop (Giller and Wilson, 1991) [7]. Moreover, the cropping approach makes use of legume intercrops since they reduce weed growth and soil erosion (Giller and Cadisch, 1995; Exner and Cruse, 1993) [8, 5]. n chickpeas, weed infestation results in intense competition that can cut yields by up to 75%. Ineffective weed control techniques are one of the main things limiting the chickpea output. The growth of the crop is restricted by weeds because they can absorb nutrients and water more quickly than the crop. According to Schwezel and Thomas (1971) [14], weeds use three to four times as much nitrogen, potassium, and magnesium as a crop free of weeds.

In their early stages, chickpeas grow very slowly and have a small stature, which renders them more vulnerable to weed damage (Chaudhary *et al*., 2005) [3]. According to Singh and Singh (2000) [15], the first sixty days are the most important for the weed-crop competitiveness with the chickpea crop. In addition to significantly reducing wheat productivity, weeds have an adverse effect on crop quality. Depending on the kind, severity, and life cycle of the weed, weeds can reduce wheat output by anywhere from 10% to 80% (Jat *et al*., 2003) [9]. It has been observed that unmanaged weeds can cut wheat grain output by as much as 66% (Kumar *et al*., 2020) [10]. Weeds should be pulled from the field between 0 and 30 days after sowing, during the critical time of competition, in order to maximize wheat output (Saha *et al*., 2016) [13]. Weeds could cause significant yield losses if they were not managed during this critical phase of crop growth (Kumar *et al*., 2011) [11]. For wheat crops, weed stress and damage from poisonous chemicals discharged into the rhizosphere of grain plants were frequent issues (Anderson, 1983) [1]. Herbicide-treated plots might have exhibited the lowest plant height because the herbicides affected the plant by lowering plant height and other growth characteristics, and they also greatly reduced weed infestation. Pre-emergence herbicides produce a toxin in the upper soil layer that, when applied to the soil, partially affects crop development as well as the germination of weed seeds (Barker 2007) [2]. The current study was carried out to assess the impact of various herbicides on the growth, production, and economics of crops in a wheat-chickpea intercropping system in perspective of these facts.

Materials and Methods

A field experiment was carried out at the Lovely Professional University's School of Agriculture in Phagwara, Punjab, during the 2020–2021 Rabi season. The soil in the experimental field had a pH of 8.1 and was sandy loam. The soil's available nitrogen, phosphorus, and potassium contents were medium (182.27 kg/ha, 19.64 kg/ha, and 184.56 kg/ha), while its organic carbon concentration was low (0.20 percent). Eight treatments, including T1-Pendimethalin 1000 ml/ha (PE), T2-Isoproturon 1000 g/ha (PoE), T3-Cladinofop-propargyl 60 g/ha (PoE), T4-Pinoxaden 50 g/ha (PoE), and T5-Hand weeding at 60 DAS, were used in the Randomized Block Design (RBD) setup for the trial. The wheat variety Unnat-PBW-343 and the chickpea variety GNG-469 were sown with a row-to-row spacing of 30 cm and an intercropping ratio of 2:1. In order to get data on the amount of dry matter accumulated per crop, each plant was cut from the ground in a row that was 25 cm long. It was then sun dried and kept at 65°C in an electric oven to ensure a consistent weight. Ten randomly tagged plants from each plot were used to measure plant height. With the assistance of the spad meter, the chlorophyll index of the tagged plants was determined. From a length of one meter, the number of wheat tillers was counted. Using the appropriate formulas, the Crop Growth Rate (CGR) and Relative Growth Rate (RGR) were determined.

$$CGR = \frac{W2 - W1}{T2 - T1} \times \frac{1}{A}$$

$$RGR = \frac{\text{Log e } W2 - \text{Log e } W1}{T2 - T1}$$

Ten tagged plants from each crop in each plot were used to gather data on yield attributes. Using their corresponding calculations, the harvesting index and the B:C ratio were determined.

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

$$\text{Benefit Cost (B:C)} = \frac{\text{Net returns}}{\text{Cost of cultivation}}$$

Results and Discussion

Growth parameters of wheat: - Table 1 data showed that, with the exception of metribuzin 250 g/ha (PE), all weed control treatments improved wheat growth parameters as compared to weedy control. Weed free check data included the greatest significant plant height, dry matter accumulation per plant, number of tillers per running meter, chlorophyll index, CGR, and RGR. Among the herbicide treatments, pendimethalin 1000 ml/ha (PE) had the highest plant height, the most tillers per running meter, the highest CGR and RGR of wheat, the highest dry matter accumulation per plant, and the highest chlorophyll index. Pendimethalin 1000 ml/ha (PE) also had the highest chlorophyll index among the herbicide treatments, and it was comparable to isoproturon 1000 g/ha (PoE) and cladinofop-propargyl 60 g/ha (PoE). Metribuzin 250 g/ha (PE) had the lowest wheat growth characteristics because it is phytotoxic to wheat crops. Ralphs *et al*., 1998 reported identical phyto-toxicity results for metribuzin 250 g/ha (PE). However, superior wheat crop growth outcomes were obtained by applying 1000 ml/ha of pendimethalin (PE), as reported by Pandey *et al*., in 2020 [12].

Growth parameters of chickpea: - As shown in Table 2, all of the weed management treatments considerably improved the chickpea growth parameters over the weedy check. The weed-free check had the highest significant plant height, dry matter accumulation per plant, chlorophyll index, CGR, and RGR values. Of all the herbicide treatments, pendimethalin 1000 ml/ha (PE) had the tallest chickpea plant height, which was at par with isoproturon 1000 g/ha (PoE) and cladinofop-propargyl 60 g/ha (PoE). Pendimethalin 1000 ml/ha (PE) also had the highest dry matter accumulation per plant, which was at par with isoproturon 1000 g/ha (PoE). Similar findings were also published by Singh *et al*., in 2020 [16]. The chickpea's chlorophyll index did not alter much.

The pendimethalin 1000 ml/ha (PE) yielded the highest CGR and RGR, however. The weedy check showed the lowest chickpea growth parameters. Javed *et al*., (2018) [17] also found results that were identical.

Effect on yield attributes of wheat: With the exception of metribuzin 250 g/ha (PE), the data in Table 3 showed that all weed management techniques improved the yield attributes of wheat over weedy check. The weed-free check revealed the most excellent wheat yield qualities.

Among the herbicide treatments, pendimethalin 1000 ml/ha (PE) had the highest significant spike length, number of spikelets per spike, effective tillers per running meter, number of grains per spike and test weight. Metribuzin 250 g/ha (PE) had the lowest yield qualities of wheat, mostly because it is phytotoxic to wheat crops. Fahad *et al*., (2013) [6] also reported findings that were comparable.

Table 1: Effect of different herbicides on growth parameters of wheat

Treatments	Plant height (cm)	Dry matter accumulation per plant (g)	Chlorophyll index	Number of tillers per running meter	Crop Growth Rate (g m^2 day^{-1})	Relative Growth Rate (g g^{-1} day^{-1})
Pendimethalin 1000 ml/ha (PE)	114.5	50.7	46.3	106.0	0.00400	0.5
Isoproturon 1000g/ha (PoE)	113.7	45.6	44.0	103.0	0.00377	0.5
Cladinofop-propargyl 60 g/ha (PoE)	111.6	43.1	43.0	101.3	0.00359	0.5
Pinoxaden 50 g/ha (PoE)	106.9	40.9	41.5	103.3	0.00343	0.4
Hand weeding at 60 DAS	113.8	46.6	45.4	98.7	0.00363	0.5
Metribuzin 250 g/ha (PE)	102.7	35.0	38.1	87.3	0.00292	0.4
Weedy Check	106.8	39.9	42.8	99.7	0.00332	0.4
Weed free check	116.4	51.3	47.6	108.3	0.00395	0.5
SE(m±)	1.8	2.0	1.5	1.6	0.0	0.0
CD (p = 0.05)	5.4	6.0	4.5	0.9	0.00059	0.07

Table 2: Effect of different herbicides on growth parameters of chickpea

Treatments	Plant height (cm)	Dry matter accumulation per plant (g)	Chlorophyll index	Crop Growth Rate (g m^2 day^{-1})	Relative Growth Rate (g g^{-1} day^{-1})
Pendimethalin 1000 ml/ha (PE)	61.6	6.9	41.9	0.00059	0.0761
Isoproturon 1000g/ha (PoE)	59.1	5.7	40.0	0.000484	0.0624
Cladinofop-propargyl 60 g/ha (PoE)	57.7	4.6	40.1	0.000346	0.0484
Pinoxaden 50 g/ha (PoE)	56.4	3.7	41.2	0.000289	0.0372
Hand weeding at 60 DAS	60.3	5.6	41.7	0.000503	0.0649
Metribuzin 250 g/ha (PE)	55.6	3.5	40.3	0.000277	0.0357
Weedy Check	45.4	3.3	39.4	0.000257	0.0331
Weed free check	61.8	7.0	42.5	0.000609	0.0785
SE(m±)	1.5	0.5	0.8	0.0	0.0
CD (p = 0.05)	4.4	1.5	NS	0.00016	0.022

Effect on yield attributes of chickpea: Data on chickpea yield attributes shown in Table 4 showed that all weed management treatments improved chickpea production attributes over weedy check. The weedy check had the best chickpea yield characteristics. Among the herbicide treatments, pendimethalin 1000 ml/ha (PE) produced the most pods per plant, matching isoproturon 1000 g/ha (PoE) and cladinofop-propargyl 60 g/ha (PoE) in terms of pod counts. Pendimethalin 1000 ml/ha (PE) also produced the most primary and secondary branches and seed index.

Table 1: Effect of different herbicides on yield attributes of wheat

Treatments	Length of spike (cm)	Number of spikelets per spike	Number of grains per spike	Effective tillers per running meter	Test weight (g)
Pendimethalin 1000 ml/ha (PE)	11.3	19.7	60.2	100.7	47.7
Isoproturon 1000g/ha (PoE)	10.8	18.8	53.4	99.7	44.7
Cladinofop-propargyl 60 g/ha (PoE)	10.4	18.4	53.2	99.0	43.3
Pinoxaden 50 g/ha (PoE)	10.3	18.3	52.5	98.3	43.0
Hand weeding at 60 DAS	11.3	19.4	59.0	101.3	44.7
Metribuzin 250 g/ha (PE)	10.1	17.9	48.8	89.7	42.0
Weedy Check	10.1	18.0	43.0	97.7	43.0
Weed free check	11.5	20.9	60.7	102.7	49.3
SE(m±)	0.3	0.5	3.5	1.3	0.8
CD (p = 0.05)	0.8	1.5	10.4	3.9	2.3

The amount of seeds in each pod did not differ much. The chickpea yield attributes with the lowest values were found in the weedy check. These outcomes coincided with those published by Pandey *et al*., in 2020 [12].

Table 2: Effect of different herbicides on yield attributes of chickpea

Treatments	Number of pods per plant	Number of seeds per pod	Number of branches		Seed index (g)
			Primary	Secondary	
Pendimethalin 1000 ml/ha (PE)	41.5	1.5	3.0	5.3	22.6
Isoproturon 1000g/ha (PoE)	37.9	1.5	2.8	3.3	22.2
Cladinofop-propargyl 60 g/ha (PoE)	36.4	1.0	2.7	3.7	22.2
Pinoxaden 50 g/ha (PoE)	33.8	1.0	2.3	3.2	22.0
Hand weeding at 60 DAS	40.7	1.5	2.7	4.3	22.8
Metribuzin 250 g/ha (PE)	30.8	1.0	2.7	3.0	22.1
Weedy Check	26.4	1.0	2.2	2.7	21.5
Weed free check	42.3	1.5	3.2	6.0	22.9
SE(m±)	2.6	0.1	0.2	0.3	0.3
CD (p = 0.05)	7.7	NS	0.5	0.8	0.7

Effect on yield and economics: All weed management treatments outperformed the weedy check in terms of yield, harvest index, and B:C ratio, according to data shown in Table 5. The weed-free check had the largest output of grains and straw, as well as the highest harvest index and B:C ratio. Among the herbicide treatments, pendimethalin 1000 ml/ha (PE) had the highest grain and straw yield, harvest index, and B:C ratio. The harvest index, B:C ratio, and grain and straw production were all lowest in the weedy check. Because metribuzin 250 g/ha (PE) is phytotoxic in the early stages of wheat growth, it yielded the lowest amount of grain and straw. Doba *et al*., 2021 [4], published findings that were comparable.

Table 3: Effect of different herbicides on yield and economic

Treatments	Wheat			Chickpea			B: C
	Grain	Straw	Harvest index (%)	Grain	Straw	Harvest index (%)	
Pendimethalin 1000 ml/ha (PE)	3783.3	3886.7	49.3	1271.3	1553.3	45.0	2.3
Isoproturon 1000g/ha (PoE)	3420.0	3543.3	49.1	920.0	1178.0	43.8	1.9
Cladinofop-propargyl 60 g/ha (PoE)	3360.0	3504.7	49.0	813.3	1100.0	42.6	1.7
Pinoxaden 50 g/ha (PoE)	3173.3	3340.0	48.7	692.7	943.3	42.1	1.5
Hand weeding at 60 DAS	3620.0	3780.0	48.9	1231.3	1670.0	42.3	1.8
Metribuzin 250 g/ha (PE)	2973.3	3123.3	48.5	605.0	880.0	42.5	1.4
Weedy Check	3033.3	3210.0	48.8	303.3	448.3	40.3	1.2
Weed free check	4240.0	4297.0	49.7	1475.0	1750.0	45.7	2.0
SE(m±)	177	182	0.3	55.9	62.2	1.8	-
CD (p = 0.05)	539	552.1	NS	169.4	188.8	NS	-

Conclusion

The results mentioned above led to the conclusion that the best way to improve the growth parameters of both wheat and chickpea was to apply pendimethalin 1000 ml/ha prior to emergence. These parameters included plant height, dry matter accumulation per plant, chlorophyll index, number of tillers per running meter, RGR, CGR, and yield-attributing characteristics like number of spikelets per spike, spike length, number of grains per spike, effective tillers per running meter, test weight, and plant number of pods, primary and secondary branches, and crop seed index. The highest grain and straw yield, harvest index, and B:C ratio were obtained by applying 1000 ml/ha of pendimethalin (PE). The treatment with pendimethalin 1000 ml/ha (PE) remained at par with application of Isoproturon 1000g/ha (PoE) for majority of the growth measurements and yield contributing features of both wheat and chickpea crops. The application of pendimethalin 1000 ml/ha (PE) produced the highest grain and straw yields among the chemical treatments, with isoproturon 1000 g/ha (PoE) coming in second. The treatment of pendimethalin 1000 ml/ha (PE) and isoproturon 1000 g/ha (PoE) had the highest B:C ratios. Metribuzin 250 g/ha (PE) was found to have phytotoxic effects on wheat crops, which had an impact on the crop's growth, development, and yield. Metribuzin's phytotoxicity caused poor germination in the wheat. Following germination, the plant stand was lowered, and the wheat plant's physiology was also impacted—that is, it had a weaker stem, smaller leaves, and fewer tillers. When the spike reached maturity, it was smaller and had fewer spikelets with fewer grains in it.

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