



Research Article

Effect of Plant Spacing and Weed Mulches on Yield and Weeds of Potato Crop

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Abstract | Plant spacing and weeds as mulch can together have a good effect on weed competition with the potato crop. In this regard, an experiment was conducted at the university research farm of the University of Agriculture Peshawar during the cropping season of 2020 to investigate the impact of various plant to plant spaces and weeds used as mulches on the yield of potato crop and the associated weeds infesting the crop under irrigated conditions. For the data analysis of the experiment, a two factorial statistical design was used while the treatments were replicated three times. The plant spacing was kept as factor A including the plant to plant spaces of 15, 25 and 35 cm; while the weed mulches were considered as the factor B that included the biomasses of *Cannabis sativa* and *Plantago lanceolata* as weed mulches. A hand weeding treatment and a weedy check (control) were kept as standards for comparison as ideal and worst conditions. The data were taken on various parameters of the crop and weeds including weed density (WD) (m^{-2}), fresh weed biomass (FWB) (kg ha^{-1}), no of leaves plant $^{-1}$ (NLP), plant height (PH) (cm), tuber weight (TW) (g plant^{-1}) and tuber yield (TY) (t ha^{-1}). Results revealed that the plant spacing, weed-mulches and their interactions had a significant effect on majority of the parameters studied. Among the different levels of factor A, the plant to plant space of 35 cm resulted in a significant increase in WD (108.8 m^{-2}), FWB (1609 kg ha^{-1}), NLP (28.39 plant^{-1}), and (TW) ($695.45 \text{ g plant}^{-1}$); while plant spacing of 15 cm significantly increased the PH (55 cm) and TY (20.64 t ha^{-1}). Minimum WD (77.8 m^{-2}), FWB (1128 kg ha^{-1}), NLP (23.77 plant^{-1}), and TW ($482.62 \text{ g plant}^{-1}$) were recorded in plots of 15 cm planting spacing. For factor B, the control plots had a significantly higher WD (141.78 m^{-2}), FWB (1942 kg ha^{-1}) and PH (60.63 cm); while hand weeding treatments resulted in significantly higher NLP (30.09), TW (838.8 g) and TY (25 t ha^{-1}); however, NLP of 21.4 leaves, TW of $331.6 \text{ g plant}^{-1}$ and TY of 13.6 t ha^{-1} were recorded in control plots. In conclusion, the plant spacing of 15 cm among potato seedlings in combination with the mulching of *Cannabis sativa* showed desirable results regarding weed control and crop yield under the irrigated and agro-ecological situation of Peshawar.

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Keywords | Mulches, Plant spacing, Planting density, Potato, *Solanum tuberosum* L., Weeds



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Introduction

There is an unprecedented pressure of the rapid global population growth on agricultural scientists. To cope with the expanding population, the global agricultural and food systems must be enhanced in a way to provide sufficient and quality food to all the people. Potato is one of the crops that is grown worldwide and used in a variety of food items. This crop has the capacity to fulfill the global needs. It ranks fourth after the crops of wheat, rice and maize in terms of production worldwide having higher yielding potential and nutritive values. It is grown in more than 140 countries among which 100 countries fall in the tropical or subtropical regions (Mishra *et al.*, 2024). However, one third of the entire global potato production is achieved in the developing countries.

Weed crop interaction is as old phenomenon as agriculture is itself. In addition to other potato crop production constraints, weeds also pose strong competition to the growing potato seedlings which may result in substantial reduction in the crop tuber yields. The important broadleaf weeds of potato crop in Pakistan include *Chenopodium album*, *Amaranthus retroflexus*, *Portulaca oleracea*, *Solanum nigrum*, and *Cynodon dactylon*; while the grassy weeds include *Echinochloa crus-galli*, *Phalaris minor*, and *Avena fatua*. The problematic perennial weeds are *Convolvulus arvensis* and *Cyperus rotundus*. Along with yield reduction weeds also hamper the mechanical operations in the crop particularly at the tuber harvesting stage (Knezevic *et al.*, 1995). Yield losses in potato due to weeds may be up to 42%, while weed control measure may improve the crop yield by 18–82% (Jaiswal and Lal, 1996a, b). The use of herbicides for weed control in potato crop may be economical for increase in potato yield up to 14.17% (Jan *et al.*, 2004), and also desirable yields were achieved through hand weeding treatments (Hashim *et al.*, 2003). Still, the chemical weed control is not appreciated globally. Potato is now a key vegetable crop in Pakistan to the feed the rapidly growing population of 250 million. This country is blessed with diverse ecological and edaphic resources to achieve an ideal potato production.

The total area at national level under potato crop cultivation was around 0.341 million ha, with a gross production of 8.320 million tones during the cropping season of 2022–23 (Anonymous, 2024).

Generally, around Rs. 3.0 billion are annually lost as a result of weed competition (Hassan and Marwat, 2001). One kilogram of weed biomass may result in three kilograms of potato yield loss (Banaras, 1993) in addition to the obstruction of tubers harvesting by the weeds (Knezevic *et al.*, 1995). Weeds cause more yield losses in crops than any other crop pest (Khan *et al.*, 1992). Environmental factors like soil, water, light, temperature, and micro-organisms all may play role in shaping a particular weed range and their distribution in an area.

Maintaining optimum plant population (plant to plant space) is one of the cultural means to manage weeds. With optimum crop plants population the weeds will be suppressed with less space availability to flourish. Conceptually, lower plant population may improve per plant yield, as in this way the crop plants may capture more light, nutrients and water; on the other hand, higher populations boost crop's capability of competing with surrounding weeds (Maboko *et al.*, 2011). Mulching is another method that shades the soil surface which suffocates the emerging weeds. Plant biomasses as mulch can regulate soil temperature and moisture, may suppress weeds growth, and save cost on labor. Mulching also improves the physical conditions of soil by enhancing the biological activities of the soil fauna, which can consequently improve soil fertility that results in increased potato yield (Sanni and Eleduma, 2014; Berihun, 2011).

Looking at the importance of weed control in potato crop, the field experiment was planned with the objective to assess the effect of various levels of plant spacing and different mulches on potato yield and on weed infestation.

Materials and Methods

The instant experiment was undertaken in the cropping season of 2020 at the Research Farm of the University of Agriculture Peshawar to study the effect of varying planting spaces and weed management treatments on weeds and tuber yield of potato. The planting spaces of 15, 25 and 35 cm were considered as factor A and the weed control treatments including the mulches of the biomasses of two weeds viz. *Cannabis sativa* and *Plantago* spp., along with a hand weeding treatment and a control treatment were kept as factor B.

The experiment plot was ploughed and leveled with the

help of cultivator. The soil texture was sandy clay with a pH of 7.5. Farm yard manure (FYM) was applied to the soil followed by NPK at a rate of 250:125:125 kg ha⁻¹. The experiment land was irrigation at weekly intervals in case of no rain. In each plot, a total of four ridges were kept for potato seedlings and each ridge was in length of 4 m with ridge to ridge space of 0.75 m. The potato variety used in the experiment was a local variety named Rako. The treatment size of each unit plot was 4m x 0.75m x 4 = 12m².

The weed crop parameters on which data were recorded included weed density m⁻² (WD), fresh weeds biomass (kg ha⁻¹) (FWB), number of leaves plant⁻¹ (NLP), plant height (cm) (PH), tuber weight plant⁻¹ (g) (TW) and tuber yield (t ha⁻¹) (TY). A quadrat sized one square meter was randomly applied three times in each plot and then the values were averaged to record the WD. For the FWB, all the fresh weeds in their vegetative growth stages growing in the mid three rows of each treatment were cut away, collected, and weighed using a digital balance to record FWB. The values obtained were converted to kg ha⁻¹. The plant height data of potato plants were recorded at their physiological maturity. For this purpose, in each treatment, 10 representative plants were randomly selected, their heights were measured right from soil surface to the plant tip using a graduated scale and means were calculated afterwards. By counting the leaves of five representative potato plants from each treatment and then values were averaged to determine the NLP. The data on TW was recorded by measuring

the weight of tubers of each individual plant from the five selected representative potato plants from each plot. The means of the five plants were computed later. Finally, the data on TY was recorded by collecting all the tubers from each plot, weighing the tubers with a digital balance in kilograms. The values in kg were divided by 1000 to obtain values in tons and then the final yield was calculated using the following formula.

$$\text{Tuber yield (t ha}^{-1}\text{)} = \frac{\text{Tuber yield in unit plot (kg)} \times 10000 \text{ m}^2}{\text{Area of unit plot (m}^2\text{)} \times 1000}$$

The data on all parameters were statistically analyzed using the statistical software, Statistix 8.1 under the two factorial statistical design. After getting the significant results of the F-test, the LSD test was applied to compare the treatment means at 5% probability (Steel *et al.*, 1997). The main effects are presented in tables, and the interaction effects are graphically displayed.

Results and Discussion

Weeds density m⁻²

The density of infesting weeds in a crop plays an important role in the yield related parameters of the crop confronting the competition from weeds. The data analysis exhibited a significant effect planting spaces and weed management treatments on WD (Table 1). The WD was lowest (77.8 weeds m⁻²) in plots of 15 cm planting spaces and highest WD (108.83 m⁻²) was in plots of planting space of 35 cm.

Table 1: Effect of planting spaces and weed management measures on weed density, fresh biomass of weeds and potato plants height.

Treatments	Parameters		
	Weed density (m ⁻²)	Weed biomass (kg ha ⁻¹)	Potato plant height (cm)
Planting spaces (P)			
15 cm	77.8 b	1129 c	55.00 a
25 cm	89 c	1276 b	52.48 b
35 cm	108.83 a	1609 a	50.17 c
LSD (0.05)	7.34	55.39	1.34
Weed control treatments (T)			
Mulch of <i>Cannabis sativa</i> (biomass)	74.67 c	1091 c	51.37 b
Mulch of <i>Plantago</i> spp. (biomass)	97.89 b	1613 b	52.29 b
Hand weeding (manual)	53.22 d	706 d	45.93 c
Weedy check (control)	141.78 a	1942 a	60.63 a
LSD (0.05)	8.47	63.96	1.55
Interactions significance levels			
P x T	*	*	*

Means with different alphabetical letters in the same column are significantly different under $\alpha = 5\%$ after LSD test. * = Significant.

For factor B, the WD was lowest (53.22 m^{-2}) in hand weeding plots, that was followed closely by plots in which *Cannabis sativa* weed biomass was applied as a mulch (74.67 m^{-2}); while highest WD (141.78 m^{-2}) was in control plots. The plant to plant spacing of 15 cm between potato plants smothered the growing weeds by giving them quite less room. The wider spacing of 25 and 35 cm gave enough room to the growing weeds with which the WD increased (Ara *et al.*, 2007). The biomasses of *Cannabis sativa* weed as mulch significantly reduced the WD because of the canopy coverage and shadowing the growing weeds. Though hand weeding treatment gave best results in declining the WD, still it is not practicable in case of labor shortage, or even at large scales. Mulching is reported to enhance the capability of moisture retention of soil and to improve the soil temperatures too (Dolorima *et al.*, 2014). This might have boosted the crop performance to make the crop further competitive with the infesting associated weeds. Soil mulching decreases the WD in the earlier stages of the crops (Kosterna, 2014). According to the results, the interaction effect was also significant (Figure 1).

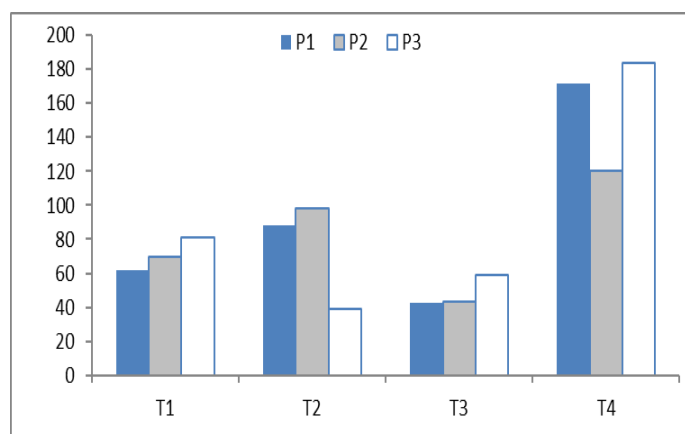


Figure 1: Interaction of planting spaces and weed management measures in potato crop regarding weed density m^{-2} .

Fresh weed biomass (kg ha^{-1})

The data analysis showed a significant effect of plant spacing and weed control treatments on FWB (Table 1). The FWB was significantly the lowest recorded value (1129 kg ha^{-1}) in plots where potato plants were spaced at 15 cm and highest FWB (1609 kg ha^{-1}) was recorded at planting spaces of 35 cm. In factor B, the FWB was lowest (706 kg ha^{-1}) in the hand weeding treatments. This was followed by the biomass of *Cannabis sativa* as mulch (1091 kg ha^{-1}). The highest FWB (1942 kg ha^{-1}) was noted in control plots. The plant to plant spaces in potato crop significantly affected the FWB. Again the narrow plant to plant

spacing of 15 cm suppressed the emerging weeds which reduced their number and biomass together, whereas the wider plant to plant spacing (i.e. 25 and 35 cm) provided sufficient room to the infesting weeds to flourish easily (Ara *et al.*, 2007). The biomass of *Cannabis sativa* weed as mulch performed effectively in declining the FWB because of the shading effect on the emerging weeds. Here also, the hand weeding resulted better in diminishing the FWB, but it is not practicable in labor shortage and at larger scales. In fact, mulching process improves the retention period of soil moisture (Dolorima *et al.*, 2014). This makes the crop further competitive with the flourishing associated weeds. The results showed a significant interaction of planting spaces and weed management measures ($P \times T$) on FWB (Figure 2).

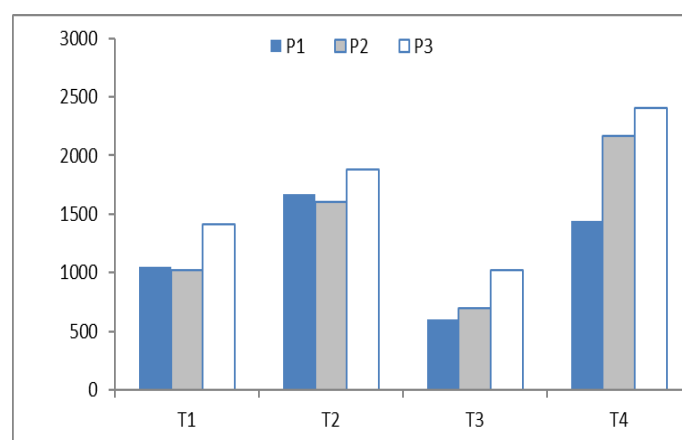


Figure 2: Interaction of planting spaces and weed management measures in potato crop regarding fresh weed biomass (kg ha^{-1}).

Plant height of potato (cm)

The data analyses indicated a significant effect of planting spaces and weed control treatments on PH of potato crop (Table 1). The PH was lowest (50.17 cm) in plant spacing of 35cm and the highest PH (55.00 cm) was recorded at planting spaces of 15 cm. The varying spaces between potato plants significantly affected the crop PH. Close plant to plant spacing of 15 cm among the potato plants enhanced the PH whereas wider plant spacing (i.e. 25 and 35 cm) decreased the average PH of potato plants. The results obtained have been found to be in similarity with the results of Papadopoulos and Ormrod (1991). They found an increase in the PH of potato at closer planting spaces. Among the weed management measures, the PH was minimum (45.93 cm) in the manual weeded treatments, followed by the biomass of *Cannabis sativa* as mulch treatments (51.37 cm); while a significantly highest PH (60.63 cm) was recorded in the control plots. As a result

of a better soil moisture retention and temperature, mulching boosted the plant height of the crop plants (Dolorima *et al.*, 2014). Mochiah *et al.* (2012) covered the soil with mulches and recorded an increase in plant height. The results indicated a significant interaction of planting spaces and weed management measures (P×T) on plant height (Figure 3).

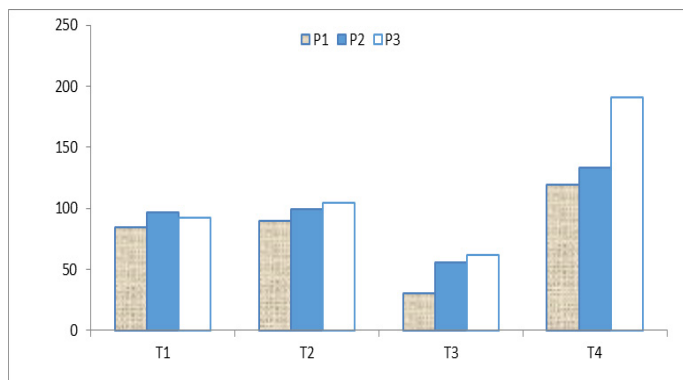


Figure 3: Interaction of planting spaces and weed management measures in potato crop regarding potato plant height. P1 (15 cm), P2 (25 cm), P3 (35 cm), T1 (mulch of *C. sativa*), T2 (mulch of *P. lanceolata*), T3 (manual weeding), T4 (control).

Number of leaves plant⁻¹

The data analysis exhibited a significant effect of planting spaces, weed management measures, and their interaction on NLP (Table 2). The NLP was recorded with the lowest average value of (24.9) at plant spacing of 15 cm, while the highest value of 29.93 was recorded at planting spaces of 35 cm. This increase in NLP with wider spacing could be attributed to the availability of more area to the growing weeds to spread and flourish. The results in similarity with those reported by Sikder *et al.* (2017), who also noted higher NLP in onion crop. As far as the weed management measures are concerned, the lowest value of NLP (21.45) was recorded in control treatments, followed by plots of mulching with biomass of *Plantago* spp. (26.80), as compared to the highest NLP (31.26) recorded in hand weeded plots. With improvement in the soil conditions like soil moisture retention etc. due to the soil mulching, the NLP was also improved (Dolorima *et al.*, 2014). Mulching also increased the no. of branches plant⁻¹ in the experiment of Gudugi *et al.* (2012). The interaction effect of the two factors (i.e. planting spaces and weed management measures) showed significant results for NLP in potato crop (Figure 4).

Tuber weight plant⁻¹ (g)

It is obvious from the data analyses that the planting spaces and weed control treatments had a significant

effect on the TW (Table 2). The TW was significantly lowest (538.4 g) under planting spaces of 15 cm, and significantly highest (751.10 g) under spaces of 35 cm. The 15 cm plant to plant spaces in potato crop resulted in a decline in the TW values while wider spacing (i.e., 25 and 35 cm) resulted in higher TW values. These results are in similarity with those of Alam (2011) that fruit weight plant⁻¹ significantly increased with increase in planting spaces. The TW was lowest (348.09 g) in control plots. This was followed by the treatments of biomass of *Cannabis sativa* weed as mulch (531.10 g), as compared with the highest TW (921.76 g) in hand weeding treatments. Mulching does have a significant effect on growth and yield of tomato (Taheri and Shamabadi, 2013). The results also showed a significant interaction of planting spaces and weed management measures (P×T) on TW (Figure 5).

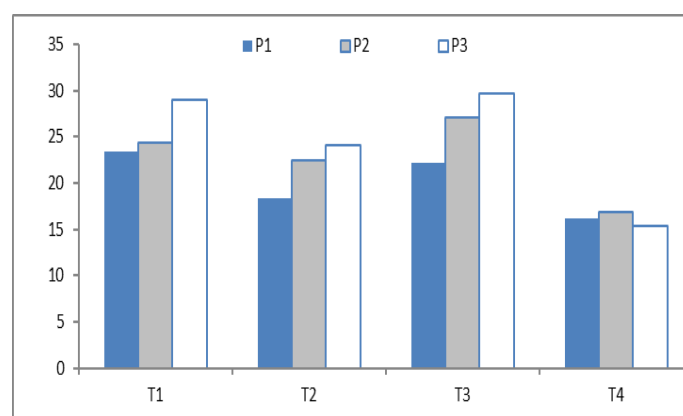


Figure 4: Planting spaces and weed management measures (P×T) interaction regarding number of leaves plant⁻¹. P1 (15 cm), P2 (25 cm), P3 (35 cm), T1 (mulch of *C. sativa*), T2 (mulch of *P. lanceolata*), T3 (manual weeding), T4 (control).

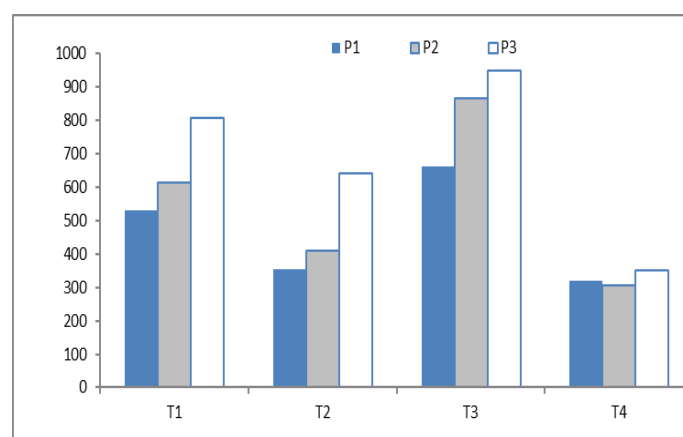


Figure 5: Planting spaces and weed management measures (P×T) interaction regarding tuber weight plant⁻¹.

Tuber yields (t ha⁻¹)

After the data analyses, it was found that the planting spaces, weed management measures and

their interactions exhibited significant effects in case of the TY parameter (Table 2). In situation of the factor A, the TY was recorded highest (21.9 t ha⁻¹) under planting spaces of 15 cm, while the lowest TY (19.11 t ha⁻¹) was recorded under planting spaces of 35 cm. However, the tuber yield ha⁻¹ was decreased when the plant to plant spacing was increased from 15 cm to 35 cm. These outcomes are in line with the results of Ahmad and Singh (2005). As far as the weed management measures are concerned, the TY was also highest (26.33 t ha⁻¹) in plots where manual weeding was done. This was followed by using the biomasses of *Cannabis sativa* weed (22.09 t ha⁻¹) and then *Plantago* spp. weed (19.49 t ha⁻¹) as mulch, in comparison with the lowest TY (14.82 t ha⁻¹) in the weedy check treatments. The manual weeding treatments showed best results in terms of yield because of effective weed control; however, it was nearly followed by the mulching treatments of the two mentioned weeds. Therefore, the mulching process effectively improved the moisture-retention-capacity of the experimental soil that also indirectly optimized the soil-temperatures (Dalorima et al., 2014). Weed competition can reduce tuber yield by up to 43% (Khan et al., 2009). Ultimately, the mulching of biomass of *Cannabis sativa* improved the tuber yield due to their shading effect on the growing weeds in the vicinity of the crop plants. The mulching effect of *Plantago* spp. was also better than the control plots.

The results showed a significant interaction effect on TY (Figure 6).

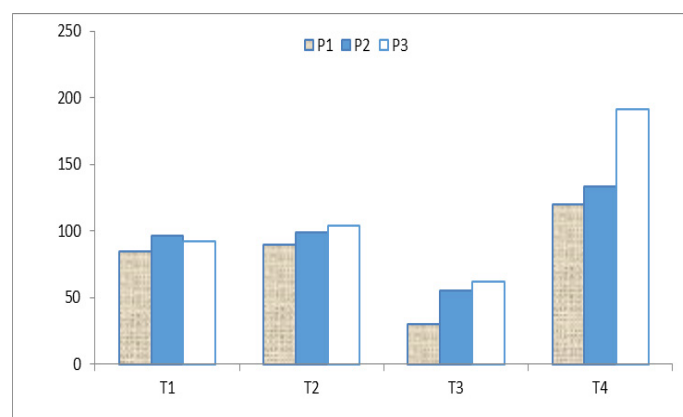


Figure 6: Planting spaces and weed management measures (P×T) interaction regarding tuber yield. P1 (15cm), P2 (25 cm), P3 (35 cm), T1 (mulch of *C. sativa*), T2 (mulch of *P. lanceolata*), T3 (manual weeding), T4 (control).

Conclusions and Recommendations

In light of the results, the planting spaces of 15 cm among the potato seedlings indicated that this is the optimum distance required for a better crop yield and effective weed control in comparison with the planting spaces of 25 and 35 cm. Among the weed control treatments, the hand weeding treatment was the best in terms of weed control and crop yield. However, it was closely followed by the mulching treatments of the

Table 2: Effect of planting spaces and weed management measures on number of leaves plant⁻¹, tubers weight plant⁻¹ (g) and tuber yield (t ha⁻¹) of potato crop.

Treatments	Parameters		
	Leaves plant ⁻¹	Tubers weight plant ⁻¹ (g)	Tuber yield (t ha ⁻¹)
Planting spaces (P)			
15 cm	23.77 c	482.62 c	20.64 a
25 cm	26.33 b	557.52 b	19.74 b
35 cm	28.39 a	695.45 a	17.92 c
LSD ($\alpha = 0.05$)	1.13	35.05	0.63
Weed control treatments (T)			
Mulch of <i>Cannabis sativa</i> (biomass)	29.16 a	658.16 b	20.93 b
Mulch of <i>Plantago</i> spp. (biomass)	25.55 b	485.33 c	18.19 c
Hand weeding (manual weeding)	30.09 a	838.82 a	25.02 a
Weedy check (control)	19.85 c	331.61 d	13.60 d
LSD (0.05) ($\alpha = 0.05$)	1.30	40.48	0.73
Interactions significance level			
P x T	*	*	*

Means with different alphabetical letters in the same column are significantly different under $\alpha = 5\%$ after LSD test. *, Significant; NS, Non significant.

biomasses of *Cannabis sativa* and *Plantago lanceolata* weeds, which indicated that hand weeding method can be replaced with mulching for environmental safety. The use of whole-plant biomasses of *Cannabis sativa* weed and *Plantago lanceolata* weed as mulch resulted in better crop performance and weed control as compared to the weedy check plots. However, mulching of the biomass of *C. sativa* was better than *P. lanceolata* in terms of weed reduction and higher tuber yields.

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Novelty Statement

The combination of planting spaces and the use of biomasses of weeds like *Cannabis sativa* and *Plantago lanceolata* as mulches to assess the effect of the biomass shading (or suffocation) on the growing weeds and at the same time to assess the effect on the yield of potato crop particularly in the agro ecological conditions of Peshawar is a novel study.

Conflict of interest

The author has declared no conflict of interest.

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