COMPARATIVE EFFICACY OF DIFFERENT HERBICIDES FOR WEED MANAGEMENT IN LENTIL (*Lens culinaris*)

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ABSTRACT

Weeds are a major threat to global crop productivity and food security. Weeds compete with plants for applied inputs and resources and resultant cause a significant reduction in final productivity. A study was conducted during 2020-21 at Agronomic Research Area, University of Agriculture, Faisalabad, comprised of two lentil cultivars and seven herbicides' treatments arranged in RCBD design having 3 replications. According to the findings, maximum root fresh and dry weight (8.07,1.57g), shoot fresh and dry weight (20,5.28 g), plant height (62.05cm), pods/plant (67.83), grains/pod (2), 1000 seed weight (25.17g), grain yield (1934 kg ha^{-1}) and biological yield (3730 kg ha^{-1}) was recorded in manual weeding and lowest root fresh and dry weight (6.28, 1.57 g), shoot fresh and dry weights (12.33,3.99 g), plant height (44.58 cm), pods/plant (42.83), grains/pod (1.17), 1000 seed wt. (14.40 g), grain yield (1113 kg ha^{-1}) and biological yield (2830 kg ha^{-1}) was recorded in weedy check. In case of cultivars, Masoor-2020 had maximum root fresh and dry weights (7.90, 1.81 g), shoot fresh and dry weights(17.17,5.02 g), plant height (54.99 cm), pods/plant (60.43), grains/pod (1.67), 1000 seed weight (21.09 g), grain yield (1690 kg ha^{-1}) and biological yield (3402 kg ha^{-1}) while Masoor-2009 had minimum root fresh and dry weight (6.53,1.68 g), shoot fresh and dry weight (14.57,4.62 g), plant height (53.09 cm), pods/plant (48.76), grains/pod (1), 1000 seed weight (18.4 g), grain yield (1586 kg ha^{-1}) and biological yield (3292 kg ha^{-1}). Manual weeding resulted in lower weeds density and biomass while weedy check in maximum weed density and biomass. Thus, it is concluded that cultivar Masoor-2020 along with manual weeding and use of Pendimethalin + S. metolachlor can be adopted to get maximum lentil production under semi-arid conditions of Faisalabad.

Keywords: Biological yield, herbicide, plant height, weed biomass and weeds

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Introduction

Lentil (*Lens culinaris*) is an imperious legume crop rich in proteins for human and animals (Rahman *et al*., 2010). Lentil contains a protein 26%, carbohydrates 60%, iron, 8%, sugars 2% and vitamin B1 1% which makes him an imperative crop for humans (*Sharara et al.,* 2011). Besides this, it also contains an appreciable number of dietary fibers, linoleic acid, oleic and palmitic acids and wide range of anti-oxidants (Roy *et al.,* 2010). Being leguminous crop, it also possesses an excellent ability to fix atmospheric nitrogen which in turn improve the soil fertility. Lentil in Pakistan is grown 6.5 thousand hectares with production of 4.9 thousand tons (Govt. of Pakistan, 2020).

The lentil production in Pakistan is very low and weeds infestation is a major reason for this lower production owing to fact that this crop is a poor competitor of weeds. Generally, weeds cause 20-30% yield losses, however poor management practices can cause yield losses up to 50% (Tanveer and Ali 2003; Rao*et al.,* 2020). Weeds not only reduce the lentil yield by competing for space, light, nutrients and water and also by releasing the different allele-chemicals in root zone of plants (Singh*et al*., 2018). It has been noted that weeds cause a loss of more than 10 Billion PKR in Pakistan (Fahad et al*.,* 2013). Different weeds attack lentil growth which causes a reduction in lentil growth and yield (Dita *et al.,* 2006).

In our country chemical weed control method is widely used method owing to the fact that it is considered to be a quick, reliable and economic technique of weed control (Khan and Haq 2004). The chemical method involves the use of different herbicides to control the weeds and different herbicides have differential effects on the weeds. There are various weed control methods which could be used for weed management. Such as physical method which includes hand hoeing while, cultural methods involves changing the sowing methods and crop rotations, chemical method is another way to manage weeds which is based on the use of different herbicides for weed control (Ahmad and Shaikh 2003; Klein *et al.,* 2006). Each of these weed control methods had its own benefits and dis-advantages. Likewise, physical and mechanical methods need labor and implements cost and chemical methods leads to environmental pollution and development of herbicide resistance (Hassan and Marwat 2001; Shrestha *et al.,*2010). Thus, weed management should not be only based on a single weed control strategy; instead, an integrated strategy should be used for long-term weed control. (Klein *et al.,* 2006).

The effectiveness of any applied herbicide depends on many factors including the pattern of weed emergence, time of application, crop stage and amount of herbicide (Hoverstad *et al*., 2004; Arooj *et al*., 2021). The timing of herbicides application is considered to be a very important factor to effects herbicides efficacy (Vandini *et al.,* 2005; Hussain*et al*., 2020). The application of Flumetsulamand imazethapyr as pre-emergence significantly control the weed infestation (broadleaf weeds) in lentil and appreciable increased the growth, biomass and grain productivity of lentil crop (Taylor *et al.*, 2020). Moreover, Fathi *et al.,* (2010) also recommended that hand hoeing followed with paraquat application resulted in significant reduction in broad and narrow weeds of lentil. Additionally, Kayan and Adak (2005) concluded that hand hoeing effectively reduced the weeds attack and increased the grain production. Therefore, in the light of aforementioned findings it is concluded that appropriate herbicides must be used to control the weeds of lentil crop.

Materials and Methods

Experimental site

A field study was carried out at agronomy research field, University of Agriculture, Faisalabad to determine the best herbicide for weed control in lentil crop. The

experimental soil was recognized as sandy loam soil with pH 7.94, organic matter contents 0.79%, total N 0.015% and available P and K 5.78 and 175 mg $kg^{-1}$by testing soil samples collected from the field. The field was cultivated two times followed with planking to prepare the final seed for sowing of lentil crop. The crop was sown in 30 cm apart rows with a plant-to-plant distance of 10 cm. The recommended doses of nutrients; N: P: K was applied at the rate of 30:60:30 kg $ha^{-1}$and all other recommended practices were kept uniform to ensure good growth and yield.

Experimental setup

The experiment was set up in randomized complete block design (RCBD) with factorial arrangement having three replications. The following treatments were used in the study:

Lentil varieties (Punjab Masoor-2009 and Punjab Masoor-2020).

Herbicides(T1: Weedy check (control), T2: Manual weed control, T3: Pendimethalin 33 EC @ 247 ml ha^{-1}, T4: S. metolachlor 960 EC @ 1976 ml ha^{-1}, T5: Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}, T6: Flumetsulam 80 WG @ 18.525 g ha^{-1} and T7: Flumetsulam 80 WG @ 24.7 g ha^{-1}).

Observations recorded

Growth parameters, such as root fresh and dry weights, were assessed by cautiously uprooting three plants from each plot, separating roots from shoots, weighing them for fresh weight, and then drying them in an oven at 65^{o}C and reweighed for dry weight.Similarly, shoots detached from roots were weighed fresh and afterwards dried in an oven to procure shoot dry weight. For chlorophyll contents SPAD-502 plus was used to record data from three different points in each leaf. The data for plant height was noted by taking five random plants and measure its length at time of harvest with the help of measuring tape and then averaged. Branches and pods $plant^{-1}$ was taken by counting number of branches and pods in five plants from each plot and taking their average. To asses grains per pod ten pods were collected from every plot, trashed and grains were counted in each pod and average was measured. After harvesting a sample of 1000 seeds was taken and weighed to obtain 1000 seed weight. Harvested biomass from each plot was collected, weighed for grain yield the harvested biomass was threshed and cleaned, the grains obtained after threshing were weighed and converted into kg ha^{-1}.The harvest index was determined by using the following formula:

$$\mathrm{HI} = \frac{Grain\ yield}{Biological\ yield} \times 100$$

Weed parameterssuch as weed density is calculated by marking an area of one square meter in each plot and manually counting weeds and these weeds were harvested and weighed to determine fresh and dry weeds weights.

Statistical analysis

The data of different parameters was analyzed by, analysis of variance (ANOVA) whereas least significant difference (LSD) test was used to compare the significant difference amid different treatment means (Steel *et al*., 1997).

Results and Discussion

4.1. Root fresh weight (g)

The results related to root fresh weight (RFW) as affected by different herbicides and cultivar are given in Table 4.1. The maximum RFW (8.07 g) was recorded in manual weeding followed closed with T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}) and lowest RFW (6.28 g) was recorded in weedy check (Table 4.1). In case of cultivars Punjab Masoor-2020 had maximum RFW (7.90 g) while Punjab Masoor-2009 had minimum RFW (6.53 g). In interactive effect maximum RFW was recorded in Punjab Masoor-2020 with manual weeding followed by T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}) and lowest RWF was recorded in Punjab Masoor-2009 in weedy

check. The results indicated that manual weeding and application of herbicides considerably improves weeds growth which in turn ensured the better availability of resources to the plants and resulted in substantial increase in root fresh and dry biomass production these outcomes are same with findings of Khan et al.,(2011) they also noticed that herbicides application significantly reduced the weeds infestation and increased plant growth.

4.2. Root dry weight (g)

The results presented in Table 4.2 indicated that different herbicides application and cultivars had significant impact on root dry weight (RDW), however, interactive of herbicides application and cultivars had non-significant impact on RDW. The maximum RDW (1.92 g) was noted in manual weeding that remained same with T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}), while lowest RFW (1.57 g) was recorded in weedy check that was also at par with T_6 (Flumetsulam 80 WG @ 18.525 g ha^{-1}).Among cultivars Punjab Masoor-2020 had maximum RDW (1.81 g) while Punjab Masoor-2009 had minimum RDW (1.68 g). The hand weeding produced maximum RDW followed by T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}). All the herbicides and manual weeding reduced the weeds growth which in turn ensured the better availability of inputs and resources for plants and therefore, resulted in substantial increase in root fresh and dry biomass production. These results are comparable with outcomes of Wujek *et al.*, (2012) and Deveikte *et al.,*(2015) they also noted that herbicides reduced the weed crop competition and resulted in significant increase in the biomass production.

4.3. Shoot fresh weight (g)

The results indicated that different herbicides application and lentil cultivars had significant impact on shoot fresh weight. Nonetheless, interactive effect of herbicides application and cultivars had non-significant impact on the SFW (Table 4.3). The maximum SFW (20.08 g) was recorded in manual weeding followed closely with T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}) and lowest SFW (12.33 g) was recorded in weedy check. Amongst cultivars Punjab Masoor-2020 had maximum SFW (17.17 g) while Punjab Masoor-2009 had minimum SFW (14.57 g). All the herbicides and manual weed control reduced the weeds growth which in turn ensured the better availability of inputs and resources for lentil plants and therefore, resulted in substantial increase shoot biomass. These results are comparable with outcomes of Wujek *et al.* (2012) and Deveikte *et al.* (2015) they also noted that herbicides reduced the weed crop competition and resulted in significant increase in the biomass production.

4. 4. Shoot dry weight (g)

The results related to the shoots dry weight (SDW) as affected by diverse cultivars and herbicides application are presented in Table 4.4. The results indicated the significant impact of cultivars and herbicides application on SDW, however, their interaction had non-significant impact on the SDW. The maximum SDW (5.28 g) was noted in manual weeding that was remained similar with T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}) followed by T_7 (Flumetsulam 80 WG @ 24.7 g ha^{-1}) and lowest SDW (3.99 g) was noticed in weedy check. The cultivar Punjab Masoor-2020 performed appreciably well with maximum SDW (5.02 g) while cultivar Punjab Masoor-2009 remained at lowest ranking with minimum SDW (4.62 g). In the current study, herbicide application and manual weed management lower weed growth, ensuring wider reliability of inputs and resources for lentil plants and, as an outcome, a substantial increase in shoot plant biomass.These findings are consistent with the findings of Wujek et al. (2012) and Deveikte et al. (2015), who found that herbicides lowered weed crop

competition and leads to a significant increment in plant biomass.

4. 5. Chlorophyll contents

Chlorophyll contents is an imperative photosynthetic pigment which play a significant role in photosynthetic process. The results of chlorophyll contents as affected by different cultivars and herbicides application are given in Table 4.5. The results showed that herbicides application and cultivars had significant impact on the chlorophyll contents, however, interactive effect of herbicides and cultivars had non-significant impact chlorophyll contents. The maximum chlorophyll contents (1.49) was recorded in weedy check that was similar with T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}) and lowest chlorophyll contents (1.20) was recorded in weedy check. In case of cultivars Punjab Masoor-2020 had maximum chlorophyll contents (1.41) while Punjab Masoor-2009 had lowest chlorophyll (1.28) contents. In present research the maximum chlorophyll contents were recorded with hand weed control after that T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}). The present findings are in line with those of Tepe et al.,(2004) they confirmed that herbicide application reduced the adverse effect of weeds and ensured the better availability of magnesium and nitrogen which are considered to be crucial for chlorophyll synthesis.

4.6. Plant height (cm)

Plant height is an imperious growth parameter which is significantly affected by the growing conditions and genetics of plants. The data given in Table 4.6 indicated herbicides application and lentil cultivars had significant impact on plant height, while their interactive effect had non-significant impact on the plant height. The taller plants with maximum height (62.05 cm) was recorded in manual weeding that remained similar with T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}) and lowest plant height (44.58 cm) was noted in weedy check. Among cultivars Punjab Masoor-2020 had maximum plant height (54.99 cm) while Punjab Masoor-2009 had minimum plant height (53.09 cm). The taller plants with more height was noted in manual weed control however, it remained same with T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}). The manual weed control and herbicides application induced the suitable conditions which favors the better vegetative growth. Moreover, the reduction in plant height was recorded in weedy check which can be attributed to growth inhibition induced by weeds created due to competition between resources and applied inputs Chachar *et al.,*(2009).

4.7. Branches per plant

This is imperative yield contributing trait in lentil crop. Greater the branches/plant more will be grain yield. The results indicated that herbicides application and cultivar significantly affected the branches/plant, however, their interactive effect remained non-significant (Table 4.7). The maximum branches/plant (12.83) was recorded in manual weeding that remained same with T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}) followed by T_7(Flumetsulam 80 WG @ 24.7 g ha^{-1}) with branches/plant of (11.67) and lowest branches/plant (10.67) was noted in weedy check. In case of cultivars Punjab Masoor-2020 had maximum branches/plant (11.86) while Punjab Masoor-2009 had minimum branches/plant. The branches/plant were significantly increased in hand weeding and chemical weed control as compared to weedy check. The hand weeding and herbicides cause a marked reduction in weeds infestation which resulted in better availability of assimilates, nutrients and other inputs to crop which therefore favors the substantial increase in yield traits Chachar et al.,(2009).

4.8. Pods per plant

The results indicated that herbicides application and cultivars significantly

affected the pods/plant, moreover, interaction effect of herbicides application and cultivars also significantly affected the pods/plant (Table 4.8). The maximum pods/plant (67.83) was recorded in manual weeding followed by T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}) and T_7 (Flumetsulam 80 WG @ 24.7 g ha^{-1}) and lowest pods/plant (42.83) was recorded in weedy check. As for cultivars, Punjab Masoor-2020 had maximum pods/plant (60.43) while Punjab Masoor-2009 had lowest pods/plant. In interactive effect maximum pods/plant was recorded in Punjab Masoor-2020 with manual weeding followed closely with application of Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1} and lowest pods/plant was noted in Punjab Masoor-2009 in weedy check. The use of manual weeding and application of pre and post emergence herbicides caused a marked increment in pods/plant as well as efficiently controlled the weeds which enables the lentil plants to obtain maximum nutrients, water and other inputs under reduce weed competition which increased pod/plants (Hassan et al., 2010; Kandil and Kordy, 2013).

4.9. Grains per pod

The results indicated that different herbicides had cultivars significantly affected the grains/pod, however, their interaction had non-significant impact on grains/pod (Table 4.9). The maximum grains/pod were recorded in manual weeding that remained same with T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}) and lowest grains/pod was recorded in weedy check. In case of cultivars Punjab Masoor-2020 had maximum grains/pod while Punjab Masoor-2009 has minimum grains/pod. The overall observation depicted that with low weeds density enhances the number of grains per cob due to continues and adequate availability of photosynthates.The combined application of pre and post emergency herbicide application (T_5) remained the top performed with respect grains/pod. These outcomes are same with results of Soliman and Gharib, (2011); Imoloame and Omolaiye, (2016)whom notice a significant weed suppression by herbicides application allowed the plants to convert more energy into assimilates production which is used to produce more grains.

4.10. 1000 grain weight (g)

The results indicated that herbicides application and cultivars significantly affected the 1000 grain weight, while their interaction effect also significantly affected the 1000 grain weight (Table 4.10). The maximum 1000 grain weight (25.17 g) was recorded in manual weed control followed by T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}) and T_7 (Flumetsulam 80 WG @ 24.7 g ha^{-1}) and lowest 1000 grain weight (14.40 g) was noted in weedy check. Cultivar Punjab Masoor-2020 had maximum 1000 grain weight (21.09 g) whereas Punjab Masoor-2009 had minimum 1000 grain weight (18.44 g). In interaction maximum 1000 grain weight was recorded in Punjab Masoor-2020 with manual weeding while minimum 1000 grain weight was recorded in Punjab Masoor-2009 with weedy check. The variable herbicides application and hand weeding significantly increased the 1000 grain weight. This increase in 1000 grain weight can be attributed to proper water and nutrient utilization, resulted in vigorous growth and assembling more assimilates in grains (Bakht *et al.,* 2011; Tesfay *et al*.,2014).

4.11. Grain yield (kg ha^{-1})

The results indicated that different herbicides and cultivars significantly affected the grain yield, similarly, their interactive effect of herbicides and cultivars also had significant impact on the grain yield (Table 4.11). The maximum grain yield (1934 kg/ha) was noticed in manual weeding followed by T_5 (Pendimethalin plus S. metolachlor @

2223 ml ha^{-1}) and T_7 (Flumetsulam 80 WG @ 24.7 g ha^{-1}) and lowest grain yield (1113 kg/ha) was recorded in weedy check (Table 4.11). Amid cultivars Punjab Masoor-2020 had maximum grain yield (1690 kg/ha) while Punjab Masoor-2009 had minimum grain yield. In interactive effect of both factors maximum grain yield was recorded in Punjab Masoor-2020 with manual weeding while minimum grain yield was recorded in Punjab Masoor-2009 with weedy check. The maximum grain yield was noted in manual weeding followed by T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}). These results are similar with theconclusions of Brand *et al.,*(2012); Stagnari and Pisante (2011)whom also found that weed crop competition in lentil might cause a significant yield loss.

4.12. Biological yield (kg ha^{-1})

The results indicated that different herbicides application and cultivars significantly affected the biological yield. Similarly, interactive effect of herbicides application and cultivars also had significant impact on the biological yield (Table 4.12). The maximum biological yield (3730 kg/ha) was recorded with manual weed control followed by T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}) and lowest biological yield (2863 kg/ha) was recorded in weedy check. The cultivar Punjab Masoor-2020 had maximum grain yield (3402 kg/ha) while cultivar Punjab Masoor-2009 had minimum biological yield (3292 kg/ha). In interactive effect of both factors maximum biological yield was recorded in Punjab Masoor-2020 with manual weeding followed by T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}) while minimum biological yield was recorded in Punjab Masoor-2009 with weedy check. The maximum biomass yield was noticed in manual weeding and herbicides application (pre and post emergence) which could be attributed to proper water and nutrient utilization and resulted in more dry matter production Adak, (2006); Kavaliauskaite and Bobinas(2006).

4.13. Harvest index

The results of harvest index (HI) are given in Table 4.13. The results indicated that diverse herbicides application and cultivars has substantiated impact on the HI. The maximum HI (51.87%) was recorded in manual weeding followed by T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}) that was also remain same with T_7 (Flumetsulam 80 WG @ 24.7 g ha^{-1}) and minimum HI (38.83%) was recorded in weedy check control. Among cultivars Punjab Masoor-2020 had maximum HI (49.41%) while Punjab Masoor-2009 had minimum HI (47.84%). In interactive effect of both factors maximum HI was recorded in Punjab Masoor-2020 with manual weeding followed byT7 (Flumetsulam 80 WG @ 24.7 g ha-1 T_5) and (Pendimethalin plus S. metolachlor @ 2223 ml ha-1) while minimum HI was recorded in Punjab Masoor-2009 with weedy check. HI is ratio of grain and biomass yield, therefore increase in HI under manual and pre and post emergence herbicides application can be attributed to increase in grain and biological yield Sirisha *et al.,*(2020).

4.14. Weed density

The various herbicides application significantly affected the weeds density, nonetheless, cultivars and interactive effect of cultivars and herbicides application had non-significant impact on the weeds density (Table 4.14). The maximum weed density (76.67) was recorded in weedy check followed by T_6 (Flumetsulam 80 WG @ 18.525 g ha^{-1}) and T_3(Pendimethalin 33 EC @ 247 ml ha^{-1}) and lowest weeds density (0) was recorded in Manual weeding and T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}). All the herbicides' treatments cause a significant reduction in weeds, however, combined application remained most superior. These findings are same with the outcomes of Meena and Jadon (2009) who also found that

application of herbicides substantially reduced the weed density in lentil crop.

4.15. Weeds fresh weight (g)

The weeds fresh weight (WFW) as influenced by diverse herbicides application and cultivars are given in Table 4.15. The results indicated that only herbicides application had significant impact on WFW, however, cultivars and interactive effect of cultivars and herbicides had non-significant impact on the WFW. The maximum WFW (48.33 g) was noted in weedy check followed by T_6 (Flumetsulam 80 WG @ 18.525 g ha^{-1}) and T_4 (S. metolachlor 960 EC @ 1976 ml ha^{-1}) and lowest WFW was recorded in weedy check (0) and T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}). Herbicides also reduced the weeds biomass by killing the weeds due to their phyto-toxicity Upadhay *et al.*(2012).

4.16. Weeds dry weight

The weeds dry weight (WDW) as affected by diverse herbicides application and cultivars are presented in Table 4.16. The results indicated that diverse herbicides application significantly affected the WDW, however, cultivar and interaction of herbicides application and cultivars had non-significant impact on the WDW (Table 4.17). The maximum WFW (18.58 g) was noted in weedy check followed by T_6 (Flumetsulam 80 WG @ 18.525 g ha^{-1}) and T_4 (S. metolachlor 960 EC @ 1976 ml ha^{-1}) and lowest WDW was recorded in manual weeding and T_5 (Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}) respectively. The lowest weeds dry biomass was recorded in hand weeding which can be due to removal of weeds at regular intervals which resulted in significant reduction in weeds biomass Rajib *et al.,*(2014).

Table 4.1. Effect of different herbicides application on root fresh weight (g) of different lentil cultivars

Herbicides application	**Lentil Varieties**		**Mean**
	Punjab Masoor-2009	**Punjab Masoor-2020**	
T_1: Weedy check (control)	5.93i	6.63g	6.28F
T_2: Manual weed control	7.25de	8.89a	8.07A
T_3: Pendimethalin 33 EC @ 247 ml ha^{-1}	6.29h	7.99c	7.14C
T_4: S. metolachlor 960 EC @ 1976 ml ha^{-1}	6.17hi	7.47d	6.82D
T_5: Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}	7.15ef	8.84a	7.99B
T_6: Flumetsulam 80 WG @ 18.525 g ha^{-1}	5.98i	7.12ef	6.55E
T_7: Flumetsulam 80 WG @ 24.7 g ha^{-1}	6.92f	8.32b	7.62B
Mean	6.53B	7.90A	
LSD (p ≤ 0.05): VR: 0.10, HA: 0.19, VR× HA: 0.268			

Mean sharing the identical letter did not change with each other at 5% probability level

Table 4.2. Effect of different herbicides application on root dry weight (g) of different lentil cultivars

Herbicides application	**Lentil Varieties**		**Mean**
	Punjab Masoor-2009	**Punjab Masoor-2020**	
T_1: Weedy check (control)	1.51	1.63	1.57F
T_2: Manual weed control	1.88	1.96	1.92A
T_3: Pendimethalin 33 EC @ 247 ml ha^{-1}	1.70	1.82	1.76CD
T_4: S. metolachlor 960 EC @ 1976 ml ha^{-1}	1.62	1.78	1.70DE
T_5: Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}	1.78	1.93	1.86AB
T_6: Flumetsulam 80 WG @ 18.525 g ha^{-1}	1.56	1.70	1.63EF
T_7: Flumetsulam 80 WG @ 24.7 g ha^{-1}	1.73	1.87	1.80BC
Mean	1.68B	1.81A	
LSD (p ≤ 0.05): VR: 0.045, HA: 0.084, VR× HA: NS			

Mean sharing the identical letter did not change with each other at 5% probability level

Table 4.3. Effect of different herbicides application on shoot fresh weight (g) of different lentil cultivars

Herbicides application	**Lentil Varieties**		**Mean**
	Punjab Masoor-2009	**Punjab Masoor-2020**	
T_1: Weedy check (control)	11.40	13.27	12.33F
T_2: Manual weed control	18.40	21.77	20.08A
T_3: Pendimethalin 33 EC @ 247 ml ha^{-1}	14.30	16.43	15.37D
T_4: S. metolachlor 960 EC @ 1976 ml ha^{-1}	13.83	15.43	14.63DE
T_5: Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}	16.53	19.53	18.03B
T_6: Flumetsulam 80 WG @ 18.525 g ha^{-1}	12.77	14.87	13.82E
T_7: Flumetsulam 80 WG @ 24.7 g ha^{-1}	14.77	18.87	16.82C
Mean	14.57B	17.17A	
LSD (p ≤ 0.05): VR: 0.58, HA: 0.53, VR× HA: NS			

Mean sharing the identical letter did not change with each other at 5% probability level

Table 4.4. Effect of different herbicides application on shoot dry weight (g) of different lentil cultivars

Herbicides application	**Lentil Varieties**		**Mean**
	Punjab Masoor-2009	**Punjab Masoor-2020**	
T_1: Weedy check (control)	3.90	4.09	3.99F
T_2: Manual weed control	5.04	5.52	5.28A
T_3: Pendimethalin 33 EC @ 247 ml ha^{-1}	4.73	5.10	4.92CD
T_4: S. metolachlor 960 EC @ 1976 ml ha^{-1}	4.61	4.91	4.76D
T_5: Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}	4.91	5.45	5.18AB
T_6: Flumetsulam 80 WG @ 18.525 g ha^{-1}	4.33	4.82	4.58E
T_7: Flumetsulam 80 WG @ 24.7 g ha^{-1}	4.81	5.23	5.02BC
Mean	4.62B	5.02A	
LSD (p ≤ 0.05): VR: 0.088, HA: 0.080, VR× HA: NS			

Mean sharing the identical letter did not change with each other at 5% probability level

Table 4.5. Effect of different herbicides application on chlorophyll contents of different lentil cultivars

Herbicides application	**Lentil Varieties**		**Mean**
	Punjab Masoor-2009	**Punjab Masoor-2020**	
T_1: Weedy check (control)	1.12	1.27	1.20F
T_2: Manual weed control	1.42	1.56	1.49A
T_3: Pendimethalin 33 EC @ 247 ml ha^{-1}	1.30	1.40	1.35CD
T_4: S. metolachlor 960 EC @ 1976 ml ha^{-1}	1.22	1.35	1.29DE
T_5: Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}	1.38	1.54	1.46AB
T_6: Flumetsulam 80 WG @ 18.525 g ha^{-1}	1.16	1.31	1.24EF
T_7: Flumetsulam 80 WG @ 24.7 g ha^{-1}	1.35	1.44	1.39BC
Mean	1.28B	1.41A	
LSD (p ≤ 0.05): VR: 0.039, HA: 0.074, VR× HA: NS			

Mean sharing the identical letter did not change with each other at 5% probability level

Table 4.6. Effect of different herbicides application on plant height (cm) of different lentil cultivars

Herbicides application	**Lentil Varieties**		**Mean**
	Punjab Masoor-2009	**Punjab Masoor-2020**	
T_1: Weedy check (control)	43.47	45.70	44.58E
T_2: Manual weed control	61.23	62.87	62.05A
T_3: Pendimethalin 33 EC @ 247 ml ha^{-1}	53.83	56.57	55.20C
T_4: S. metolachlor 960 EC @ 1976 ml ha^{-1}	50.23	52.83	51.53D
T_5: Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}	59.77	60.47	60.12AB
T_6: Flumetsulam 80 WG @ 18.525 g ha^{-1}	46.20	47.60	46.90E
T_7: Flumetsulam 80 WG @ 24.7 g ha^{-1}	56.87	58.90	57.88B
Mean	53.09B	54.99A	
LSD (p ≤ 0.05): VR: 1.26, HA: 2.36, VR× HA: NS			

Mean sharing the identical letter did not change with each other at 5% probability level

Table 4.7. Effect of different herbicides application on branches per plant of different lentil cultivars

Herbicides application	**Lentil Varieties**		**Mean**
	Punjab Masoor-2009	**Punjab Masoor-2020**	
T_1: Weedy check (control)	10.33	11.00	10.67C
T_2: Manual weed control	12.33	13.33	12.83A
T_3: Pendimethalin 33 EC @ 247 ml ha^{-1}	11.00	11.67	11.33BC
T_4: S. metolachlor 960 EC @ 1976 ml ha^{-1}	11.33	11.33	11.33BC
T_5: Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}	11.67	12.33	12.00AB
T_6: Flumetsulam 80 WG @ 18.525 g ha^{-1}	11.00	11.33	11.17BC
T_7: Flumetsulam 80 WG @ 24.7 g ha^{-1}	11.33	12.00	11.67B
Mean	11.29B	11.86A	

LSD (p ≤ 0.05): VR: 0.45, HA: 0.86, VR× HA: NS

Mean sharing the identical letter did not change with each other at 5% probability level

Table 4.8. Effect of different herbicides application on pods per plant of different lentil cultivars

Herbicides application	**Lentil Varieties**		**Mean**
	Punjab Masoor-2009	**Punjab Masoor-2020**	
T_1: Weedy check (control)	38.67i	47.00fg	42.83F
T_2: Manual weed control	65.33ab	70.33a	67.83A
T_3: Pendimethalin 33 EC @ 247 ml ha^{-1}	46.67fgh	60.00bc	53.33D
T_4: S. metolachlor 960 EC @ 1976 ml ha^{-1}	43.67ghi	58.33cd	51.00EF
T_5: Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}	55.67cde	68.67a	62.17B
T_6: Flumetsulam 80 WG @ 18.525 g ha^{-1}	41.00hi	53.33de	47.17E
T_7: Flumetsulam 80 WG @ 24.7 g ha^{-1}	50.33ef	65.33ab	57.83C
Mean	48.76B	60.43A	
LSD (p ≤ 0.05): VR: 2.23, HA: 4.17, VR× HA: 5.90			

Mean sharing the identical letter did not change with each other at 5% probability level

Table 4.9. Effect of different herbicides application on grains per pod of different lentil cultivars

Herbicides application	**Lentil Varieties**		**Mean**
	Punjab Masoor-2009	**Punjab Masoor-2020**	
T_1: Weedy check (control)	1.00	1.33	1.17C
T_2: Manual weed control	2.00	2.00	2.00A
T_3: Pendimethalin 33 EC @ 247 ml ha^{-1}	1.33	1.67	1.50BC
T_4: S.metolachlor 960 EC @ 1976 ml ha^{-1}	1.33	1.67	1.50BC
T_5: Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}	1.33	2.00	1.67AB
T_6: Flumetsulam 80 WG @ 18.525 g ha^{-1}	1.00	1.33	1.17C
T_7: Flumetsulam 80 WG @ 24.7 g ha^{-1}	1.33	1.67	1.50BC
Mean	1.33B	1.67A	
LSD (p ≤ 0.05): VR: 0.25, HA: 0.48, VR× HA: 5.90			

Mean sharing the identical letter did not change with each other at 5% probability level

Table 4.10. Effect of different herbicides application on 1000 grain weight (g) of different lentil cultivars

Herbicides application	**Lentil Varieties**		**Mean**
	Punjab Masoor-2009	**Punjab Masoor-2020**	
T_1: Weedy check (control)	14.40h	14.40h	14.40G
T_2: Manual weed control	24.17b	26.17a	25.17A
T_3: Pendimethalin 33 EC @ 247 ml ha^{-1}	17.63f	21.73c	19.68D
T_4: S. metolachlor 960 EC @ 1976 ml ha^{-1}	16.10g	19.40de	17.75E
T_5: Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}	22.00c	24.63b	23.32B
T_6: Flumetsulam 80 WG @ 18.525 g ha^{-1}	15.03gh	18.50ef	16.77F
T_7: Flumetsulam 80 WG @ 24.7 g ha^{-1}	19.73dd	22.77c	21.25C

Mean	18.44B	21.09A	
LSD (p ≤ 0.05): VR: 0.42, HA: 0.78, VR× HA: 1.11			

Mean sharing the identical letter did not change with each other at 5% probability level

Table 4.11. Effect of different herbicides application on grain yield (kg ha^{-1}) of different lentil cultivars

Herbicides application	**Lentil Varieties**		**Mean**
	Punjab Masoor-2009	**Punjab Masoor-2020**	
T_1: Weedy check (control)	1042.67l	1183.33k	1113.00G
T_2: Manual weed control	1876.33c	1993.33a	1934.83A
T_3: Pendimethalin 33 EC @ 247 ml ha^{-1}	1635.00g	1718.33f	1676.67D
T_4: S. metolachlor 960 EC @ 1976 ml ha^{-1}	1586.00h	1626.67g	1606.33E
T_5: Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}	1795.00e	1916.67b	1855.83B
T_6: Flumetsulam 80 WG @ 18.525 g ha^{-1}	1449.00j	1553.33i	1501.17F
T_7: Flumetsulam 80 WG @ 24.7 g ha^{-1}	1718.33f	1838.33d	1778.33C
Mean	1586.05B	1690.00A	
LSD (p ≤ 0.05): VR: 9.56, HA: 17.90, VR× HA: 25.31			

Means with different letters differed at 0.05 P level.

Table 4.12. Effect of different herbicides application on biological yield (kg ha^{-1}) of different lentil cultivars

Herbicides application	**Lentil Varieties**		**Mean**
	Punjab Masoor-2009	**Punjab Masoor-2020**	
T_1: Weedy check (control)	2782.33k	2945.00j	2863.67G
T_2: Manual weed control	3630.00c	3830.00a	3730.00A
T_3: Pendimethalin 33 EC @ 247 ml ha^{-1}	3343.33f	3363.33f	3353.33D
T_4: S. metolachlor 960 EC @ 1976 ml ha^{-1}	3258.67g	3274.33g	3266.50E
T_5: Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}	3541.67d	3710.67b	3626.17B
T_6: Flumetsulam 80 WG @ 18.525 g ha^{-1}	3066.67i	3150.00h	3108.33F
T_7: Flumetsulam 80 WG @ 24.7 g ha^{-1}	3422.00e	3544.00d	3483.00C
Mean	3292.10B	3402.48A	
LSD (p ≤ 0.05): VR: 11.66, HA: 21.82, VR× HA: 30.86			

Mean sharing the identical letter did not change with each other at 5% probability level

Table 4.13. Effect of different herbicides application on harvest index of different lentil cultivars

Herbicides application	**Lentil Varieties**		**Mean**
	Punjab Masoor-2009	**Punjab Masoor-2020**	
T_1: Weedy check (control)	37.47j	40.18i	38.83F
T_2: Manual weed control	51.69ab	52.05a	51.87A
T_3: Pendimethalin 33 EC @ 247 ml ha^{-1}	48.90fg	51.09bc	50.00C
T_4: S. metolachlor 960 EC @ 1976 ml ha^{-1}	48.67g	49.68ef	49.18D
T_5: Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}	50.68cd	51.65ab	51.17B

T_6: Flumetsulam 80 WG @ 18.525 g ha^{-1}	47.26h	49.31fg	48.28E
T_7: Flumetsulam 80 WG @ 24.7 g ha^{-1}	50.22de	51.87ab	51.04B
Mean	47.84B	49.41A	
LSD (p ≤ 0.05): VR: 0.32, HA: 0.60, VR× HA: 0.85			

Mean sharing the identical letter did not change with each other at 5% probability level

Table 4.14. Effect of different herbicides application on weed density

Herbicides application	**Lentil Varieties**		**Mean**
	Punjab Masoor-2009	**Punjab Masoor-2020**	
T_1: Weedy check (control)	77.33	76.00	76.67A
T_2: Manual weed control	-	-	-
T_3: Pendimethalin 33 EC @ 247 ml ha^{-1}	48.00	46.67	47.33D
T_4: S. metolachlor 960 EC @ 1976 ml ha^{-1}	58.33	56.67	57.50C
T_5: Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}	32.33	30.67	31.50E
T_6: Flumetsulam 80 WG @ 18.525 g ha^{-1}	74.00	73.00	73.50B
T_7: Flumetsulam 80 WG @ 24.7 g ha^{-1}	46.33	45.00	45.67D
Mean	48.05	46.86	
LSD (p ≤ 0.05): VR: NS, HA: 2.83, VR× HA:NS			

Mean sharing the identical letter did not change with each other at 5% probability level

Table 4.15. Effect of different herbicides application on weeds fresh weight (g)

Herbicides application	**Lentil Varieties**		**Mean**
	Punjab Masoor-2009	**Punjab Masoor-2020**	
T_1: Weedy check (control)	49.00	47.67	48.33A
T_2: Manual weed control	-	-	-
T_3: Pendimethalin 33 EC @ 247 ml ha^{-1}	40.00	38.33	39.17C
T_4: S. metolachlor 960 EC @ 1976 ml ha^{-1}	44.33	42.67	43.50B
T_5: Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}	24.00	22.33	23.17D
T_6: Flumetsulam 80 WG @ 18.525 g ha^{-1}	47.00	45.33	46.17AB
T_7: Flumetsulam 80 WG @ 24.7 g ha^{-1}	38.33	37.33	37.83C
Mean	34.67	33.38	
LSD (p ≤ 0.05): VR: NS, HA: 2.68, VR× HA:NS			

Mean sharing the identical letter did not change with each other at 5% probability level

Table 4.16. Effect of different herbicides application on weeds dry weight (g)

Herbicides application	**Lentil Varieties**		**Mean**
	Punjab Masoor-2009	**Punjab Masoor-2020**	
T_1: Weedy check (control)	18.67	18.50	18.58A
T_2: Manual weed control	-	-	-
T_3: Pendimethalin 33 EC @ 247 ml ha^{-1}	12.80	12.63	12.72D
T_4: S. metolachlor 960 EC @ 1976 ml ha^{-1}	14.60	14.50	14.55C
T_5: Pendimethalin plus S. metolachlor @ 2223 ml ha^{-1}	8.13	8.07	8.10F
T_6: Flumetsulam 80 WG @ 18.525 g ha^{-1}	16.73	16.50	16.62B

T_7: Flumetsulam 80 WG @ 24.7 g ha^{-1}	10.97	10.87	10.92E
Mean	11.70	11.58	
LSD (p ≤ 0.05): VR: NS, HA: 1.31, VR× HA:NS			

Mean sharing the identical letter did not change with each other at 5% probability level.

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