# Investigation of different mechanical weeding methods performance for weed control efficiency, mechanical injuries and yield in three bean varieties

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Abstract: In many agricultural systems around the world, competition of weeds is one of the major factors that reduce crop yield. This research was carried out to study the performance of mechanical methods for weed control, mechanical damage, yield and yield components of in 2012 and 2013 cropping seasons. The experiments were carried out as split plot complete block design with three replications in the Agricultural and Natural Resources Research and Education Center in Markazi Province, Iran, Arak. The experimental treatments were three bean varieties including (a) Sadri, (b) KS-21189 and (c) COS-16 as main plots and four mechanical methods of weeds control such as:(i) sweep type weeder,(ii) rotary type weeder, (iii) rolling type weeder and (iv) manual weeding, as subplots. The KS-21189 variety was superior by yielding 4527 kg ha-1 compared to other two varieties. The highest percentage of plant injury at 12.7% was obtained in Sadri variety with the rolling weed control method efficiency of 17.9%. Other results showed that the lowest percentage of plant injury of 1.1% and the highest weed control efficiency 91.8% were observed in the manual weeding method. However, the application of the sweep weeder leading to high bean yield of 4848 kg ha-1. Hence, the application of the Seep weeder type could be recommended for the uprooting of weeds in bean fields in the study area. Therefore, the application of the sweep type could be recommended for the uprooting of weeds in bean fields in the study area.

**Key words:** agronomic traits, bean, weeds, weeding performance, yield.

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## 1 Introduction

The bean (*Phaseolus vulgaris*) is one of the world's most consumed cereal with about 50 percent directly intended for human consumption (Mac Clean et al., 2004). The bean plant is sensitive to competition from weeds (Razaz et al., 2014). Nowadays, the use of chemical herbicides while saving time and money, has caused to resistance in more than 183 weed species and environmental pollution (Zhang, 2003; Razaz et al., 2014). Some researchers showed that mechanical row beans, greatly reduced weed development and infestations between the rows (Glowacka, 2010; Esmaeilzadeh and Aminpanah, 2015), but this method, is not effective with controlling weeds within rows (Pannacci et al., 2018).

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In general, researchers have reported that mechanical weed control enhances the performance and economic usefulness of production (Pannacci and Tei, 2014). The use of mechanical weed control machines, especially in hot and dry areas, is a good way to control weeds (Toukura et al., 2006). Furthermore, Safari and Najafi (2008) and Alexandrou and Coffing (2001), showed that the sweep type weeder and hand weeding give the highest and lowest yields respectively in terms of weed control.

Today, weed control within crop rows is done mostly by sweep type weeder (Van der Weide et al., 2008). Other researchers have shown that hilling up the plants by sweep type weeder, could increase the yield by improving the development of lateral roots that replace rotten roots of plants (Lak and Ghadiri, 2012). According to Snapp et al. (2003), the amount of lateral roots of bean increases the crop tolerance to fusarium root rot. Considering the scarcity of effective herbicides damage to the human health and environment, there is a clear need for appropriate mechanical weed management. The aim of this study was to evaluate the most appropriate method of mechanical weed control methods in the bean fields for the Arak climate.

## 2 Materials and methods

This study was carried out at the Arak agricultural research station located in the Markazi Agricultural and Natural Resources Research and Education center, Arak, Iran, in 2012 and 2013 cropping season. The city is located at 490 41'E and 340 05'N. The mountains around Arak, Miqan wetland and the Farahan plain have affected the climate of this region and have given it special features. The duration of frost days varies from 65 to 120 days at different years. The climate of the Arak region based on the Amberger methods is cold semi-arid. The average rainfall is about 341.7 mm, and its average altitude is 1700 meters above sea level. The weather parameters of the region during the experiment period are shown in the Figure 1. The soil properties of the experimental area are described in the Table 1.

**Table 1 Physical and chemical properties of soil sample**

| Soil Texture | Depth (cm) | Organic carbon (%) | Nitrogen (%) | Potassium (mg/Kg) | Phosphorus (mg/Kg) | Clay (%) | Sand (%) | Silt (%) |
|---|---|---|---|---|---|---|---|---|
| Sandy Loam | 0-30 | 0.48 | 0.05 | 233 | 14.4 | 22 | 40 | 38 |

The experiment carried out as split plot arrangement based on complete block design with three replications. The treatments consist of three bean line and varieties, including Sadri, KS-21189 and COS-16 as main plots and four mechanical weed control methods, including sweep type weeder, rotary type weeder, rolling type weeder and manual weeding as subplots. Initial germplasm and lines which used in this study were imported from the CIAT International Center for Research into Iran. Before planting, soil samples from a depth of 30 cm were taken to determine the physical and chemical characteristics of the soil (Table 1). The bean planting operation was completed on June 10th. In each plot, four rows of beans were cultivated with a spacing of 65 cm and a length of 35 meters. The spacing of the plants was 5 cm and the planting density was 308000 plants per hectare. The image of machines are showed in Figure 2. The width of each unit was 30 cm.

In this experiment, 100 kg $ha^{-1}$ urea fertilizers as a nitrogen starter and 50 kilograms of triple super phosphate fertilizer were used and irrigation operation was done by siphon. The weed control was carried out in the field before flowering stage. The climate parameters of the area during the experiment period are included in Figure 1. The weeding index and plant injury percentage were measured with the standard formula and the procedures are as follow (Chinnusammy et al., 2013). Weeding operation performed 30 days after planting date.

$$Weeding\ Index(\%) = \frac{W_1 - W_2}{W_2} \times 100 \quad (1)$$

Where, $W_1$ is the dry weight of weed in sample plot per $m^2$ before weeding in gram, $W_2$ is the dry weight of weed

in sample plot in $m^2$ after weeding in gram.

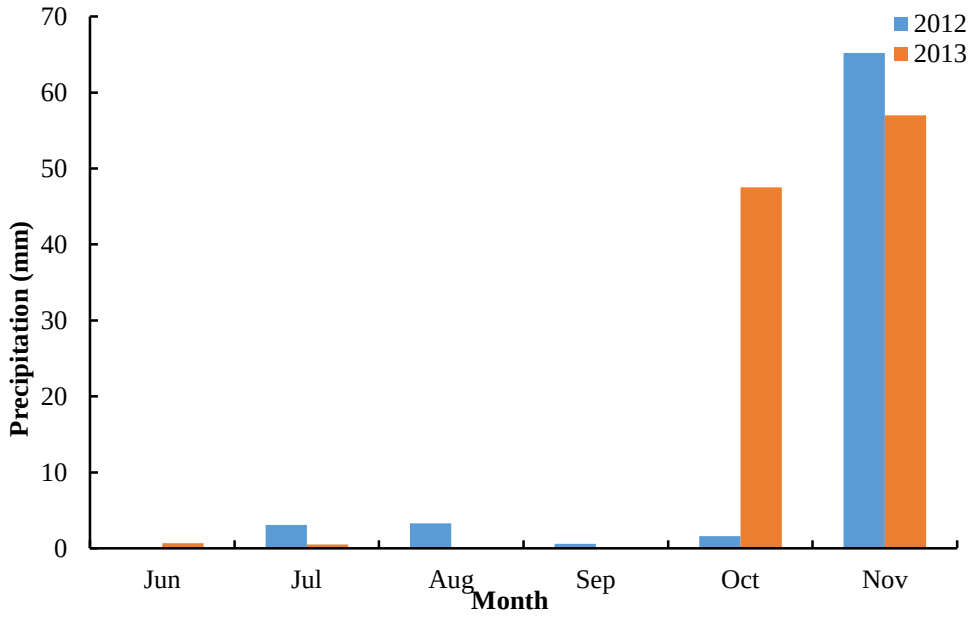
$$Plant\ injury = \frac{A}{B} \times 100 \quad (2)$$

Where, A is No. of injured plants(cut or damaged)in sample plot and B is total No. of plants in sample plot.

In the harvesting stage, for determination of grain yield per hectare, after removing the marginal effect, all the remaining plants in each plot were harvested. Then, randomly, five bean bushes were harvested from each plot and plant height, number of pods per plant and number of seeds per pod were counted and their average was recorded for each trait. After a week of drying in the open air, the bushes were threshed. The grain harvest index (HI, %) was calculated as proportion grain yield (G, kg $ha^{-1}$) and the total under-ground biomas (B, kg $ha^{-1}$) as Equation 3 (Huehn, 1993).

$$HI = \frac{G}{B} \times 100 \quad (3)$$

The grain harvest index was calculated for each experimental plot. Mean of data was analyzed by least significant diffrence LSD (Least Significant Difference) test and at a probability level of 5%.




**B**

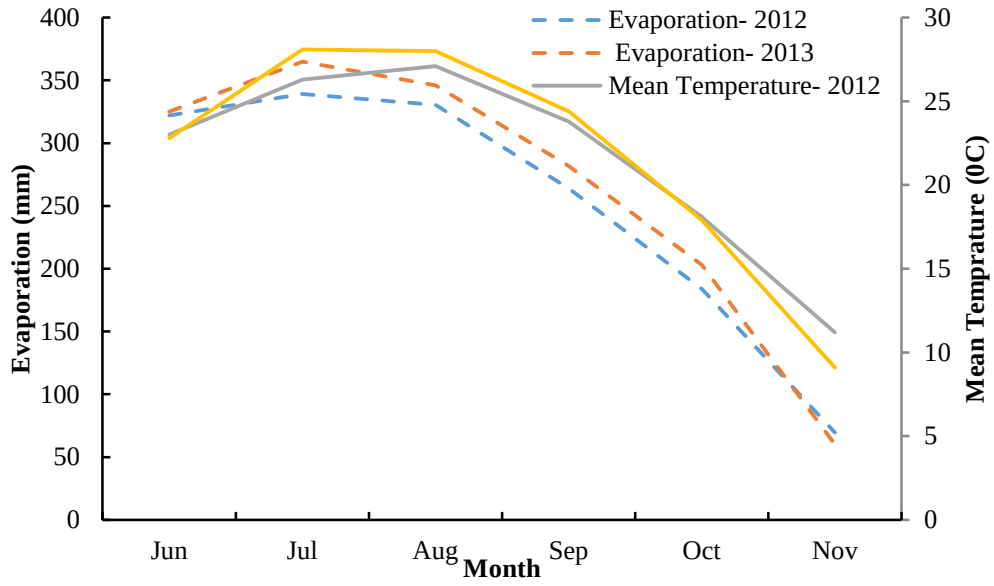



Figure 1 Weather conditions in Arak region during 2012-2013 period: A) Precepitation in different months and B) Evapotranspiration in different

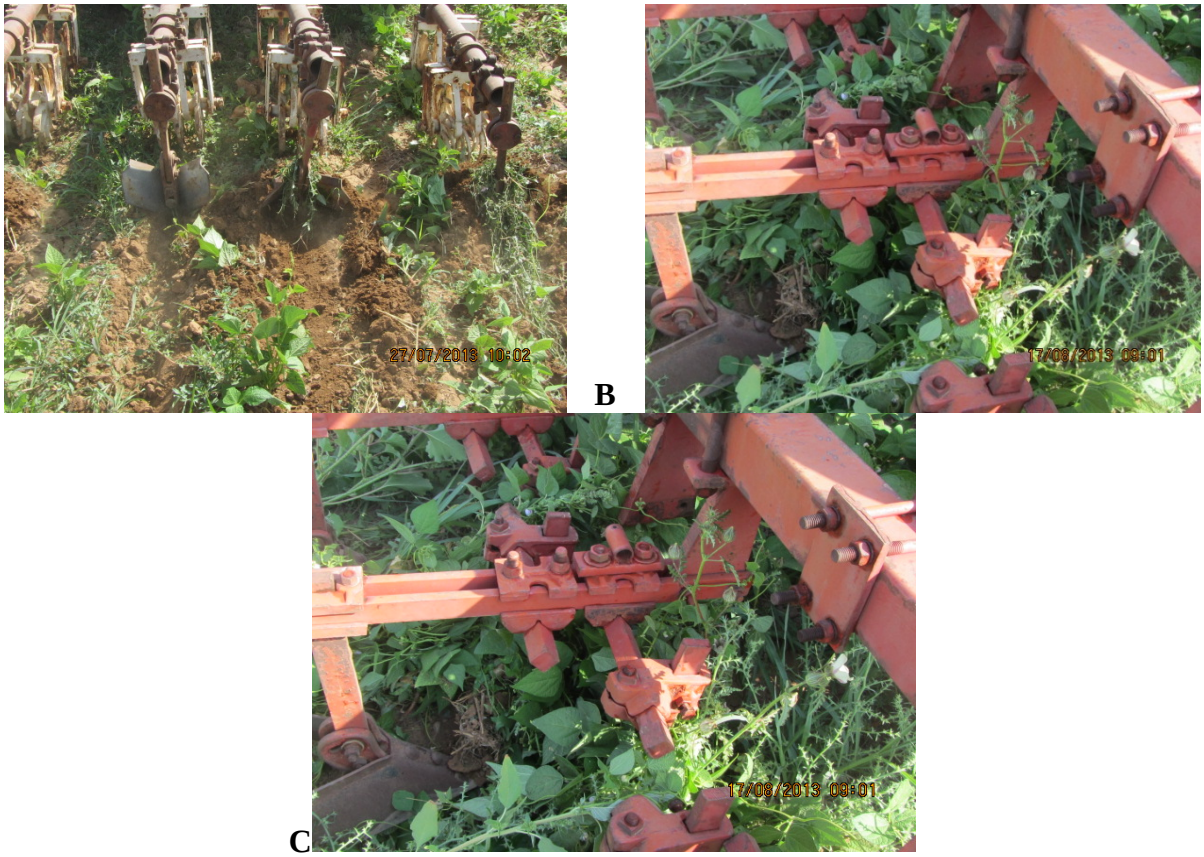



Figure2 Figures of the weeders: A) The rolling type, B) The rotary type weeder and C) The sweep type. The width of each unit was 30 cm

## 3 Results and discussion

As could be seen in Table 2, the climatic conditions in the second cropping season were desirable for plant growth and yield enhancement. This study indicated that grain yield of beans in the second cropping year was more than the first year. Results showed that crop yield could be differd from one year to another due to the difference in climatic conditions (Table 2). In this experiment, the interaction effect of year and weeding method on grain yield was significant (Table 2). Furthermore, the highest grain yield was obtained when using sweep type weeder, but different bean cultivars did not show significant statistical difference (Table 3).

**Table 2 Analysis of variance (mean square) of the measured traits in bean cultivars as affected by different weeding methods**

| Source of Changes | df | Weeding index(%) | Plant injury(%) | Harvest Index | Biomass Yield( kg ha$^{-1}$) | 100-grain weigh(g) | Seeds per Pod | Pods per Plant | Bush Height | Grain Yield(kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| *Year* | 1 | 1142* | $^{**}$36.7 | $^{**}$125.8 | $^{**}$606372900 | 9.1$^{*}$ | 0.09$^{ns}$ | $^{**}$1869.4 | 59.6$^{ns}$ | $^{*}$118220938 |
| *Year (Replication)* | 4 | 105.1 | 18.9 | 6 | 2686305 | 3.2 | 0.13 | 146.2 | 223.4 | 733310 |
| *Cultivar* | 2 | 496.3$^{ns}$ | $^{**}$94.6 | $^{**}$199.4 | $^{*}$11611302 | $^{*}$597 | $^{**}$1.04 | $^{**}$195.6 | $^{**}$1162.6 | 748435$^{**}$ |
| *Year - Cultivar* | 2 | 175.8$^{**}$ | $^{*}$16.2 | $^{**}$105.4 | $^{*}$11069049 | $^{**}$18.9 | 0.13$^{ns}$ | $^{*}$145.1 | $^{**}$1250.2 | 442149.5** |
| *Error a* | 8 | 196.8 | 4.14 | 47.5 | 4807264 | 1.1 | 0.1 | 71.6 | 50.27 | 601850 |
| *Weeding Method* | 3 | $^{*}$2352 | $^{**}$892.7 | $^{*}$46.2 | $^{*}$9422630 | $^{**}$19.5 | $^{*}$0.45 | 26.7$^{ns}$ | 9.72$^{ns}$ | $^{*}$2125303 |
| *Cultivar - Weeding Method* | 6 | 107.56$^{ns}$ | $^{**}$22.3 | 13.1$^{ns}$ | 4036239$^{ns}$ | 2.07$^{ns}$ | 0.13$^{ns}$ | 106.1$^{ns}$ | 9.56$^{ns}$ | 56414** |
| *Year - Weeding Method* | 3 | 485.91$^{*}$ | $^{**}$48.2 | $^{*}$46.5 | 1656119$^{ns}$ | 0.53$^{ns}$ | 0.02$^{ns}$ | 6$^{ns}$ | 68.33$^{ns}$ | 223336.5$^{ns}$ |
| *Year - Cultivar-Weeding Method* | 6 | 163.82$^{ns}$ | 3.7$^{ns}$ | 35.2$^{ns}$ | 3925185$^{ns}$ | 2.89$^{ns}$ | 0.1$^{ns}$ | 8$^{ns}$ | 24.80$^{ns}$ | 474392$^{ns}$ |
| *Error b* | 36 | 97.40 | 3.9 | 16.2 | 249011 | 1.08 | 0.1 | 13 | 25.29 | 409286 |
| *Coefficient of Variation (CV%)* | - | 14.21 | 18.4 | 10.5 | 13.8 | 5 | 7 | 15.9 | 8.9 | 15.5 |

Note: ns, **and* : Respectively, no significant difference, significant at a probability level of five percent and one percent.

Increment of grain yield in response to the sweep type weeder indicated its high efficiency in weed control and creating better environmental conditions for the growth of bean plants. Also, The superiority of this method in weed control were reported by other researchers (Reddiex et al., 2001; Kluchinski and Singer, 2005; Taylor et al., 2012). The usage of the sweep type weeder for weed control was soperior for grain yield increment by better eradication of weeds and the simultaneous hilling up of the bean bushes. It seems that deep softening of the soil in this method leads to greater development of bean root and better penetration of the water and air into the rhizosphere, which reduces the outbreak of the fusarium rot disease and promote bean yield. Possible reasons for reducing the grain yield of beans in the manual weeding method are the absence of hilling up the bushes.

Although, the weeding efficiency in manual weeding method is more than other methods, the weed eradication speed is slower and are done in a longer time interval and the irrigation operation is delayed. So, Due to the fact that manual weeding is time consuming process, irrigation of the field may be delayed and the crop can be encountered with water stress.

### 3.1 Bush height

The effects of cultivar and year - cultivar interaction on plant height were significant (Table 2). In this study, Sadari bean in the first cropping year had the highest plant height. The plant height of Sadri's variety decreased in the second cropping year, but the height of the two lines of KS-21189 and COS-16 increased (Table 3). In this experiment, the increament of plant height in Chitti Sadri variety in the first cropping year compared to the second cropping year could be due to the favority of climatic condition and the different reaction of bean varieties to environmental conditions.

### 3.2 Number of pods per plant

In this study, the effects of year, cultivar and interaction effect of year-cultivar on the pod number per plant were significant (Table 2). The highest number of pods per plant was obtained by using the sweep type weeder (Table 3). which was consistent with other experimental findings (Mousavi et al., 2007). This can be attributed to the hilling up the bushes, the reduction of the prevalence of Fusarium root rot disease, the possibility of timely irrigation operations and improvement of bean plant growth. Other researchers have shown that the prolongation of manual weeding operations through irrigation delays and subsequentl drought stress causes an increase in abortion of flowers and decrease in the number of pods per plant (Boutraa and Sanderz, 2001). Also, the closure of stomata reduces the photosynthesis rate of the plants, enhances the abortion of flowers and causes to decrease the number of pods per plant (Baltensperger, 2002).

### 3.3 Number of seeds per pod

The effect of cultivar and weeding method on the number of bean seeds per pod was significant at 1% probability level (Table 2). The highest number of seeds per pod was observed in the KS-21189 line. But, there was no significant differences between bean varieties. Also, the highest number of seeds per pod in beans was obtained by the use of the sweep type weeder method (Table 3). The results showed that increasing of the seeds number per pod could not significantly increase grain yield in the KS-21189 line compared to the other studied lines and cultivars. Furthermore, increment of the number of seeds per pod under the using of sweep type weeder can be due to the improvement of the environmental conditions in terms of soil permeability and the development of lateral roots and consequently increasing of the growth bean bushes.

**Table 3 Mean comparison of measured traits in three bean cultivars as affected by different weed control methods**

| Treatment | Weeding index (%) | Plant injury (%) | Harvest Index (%) | Biomass Yield (Kg/ha) | Weight of 100 Seeds(gr) | Seeds per Pod | Pods per Plant | Bush Height (cm) | Grain Yield (Kg/ha) |
|---|---|---|---|---|---|---|---|---|---|
| *Cultivar* | | | | | | | | | |
| *COS-16* | 71.4 [a] | 8.7[c] | 35.7 [b] | 11881[a] | 36.5[c] | 4.35 [b] | 20.9 [a] | 52.4 [b] | 4187 [a] |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *KS-21189* | 73.7[a] | 10.9 [b] | 38 [ab] | 11792[a] | 48.4[a] | 4.56 [a] | 21.4 [a] | 52.8 [b] | 4527[a] |
| *Sadri* | 79.9 [a] | 12.7[a] | 41.4 [a] | 10634[b] | 42.6[b] | 4.15 [b] | 20.6 [a] | 64.7 [a] | 4440 [a] |
| *Weeding method* | | | | | | | | | |
| *Manual* | 91.8 [a] | 1.1[d] | 36.7 [b] | 11180[b] | 39.5 [b] | 4.2 [b] | 21.9 [b] | 56.6 [a] | 4114 [b] |
| *Rolling* | 66.4 [b] | 17.9[a] | 37 [ab] | 11046[b] | 39.9 [b] | 4.3 [b] | 22.5[ab] | 57.1 [a] | 4134[b] |
| *Rotary* | 69.5[b] | 11.2[c] | 39.5 [a] | 11191[b] | 40.3[ab] | 4.3 b | 23.3[ab] | 57.6 [a] | 4443[ab] |
| *Sweep* | 72.5 [b] | 12.9 [b] | 39.7 [a] | 12327[a] | 41.9[a] | 4.6 [a] | 24 [a] | 57.3 [a] | 4848 [a] |

Note: The same letters indicate that there is no significant difference in the level of 5% by the LSD test

### 3.4 100-grain weight

The results showed that the effects of year, variety and weeding method on 100-grain weight in beans was significant (Table 2). The highest weight of 100-grain was obtained in the second cropping year. The KS-21189 line with semi-determinate growth habit showed the highest 100-grain weight and the COS-16 line with indeterminate growth habit showed the lowest 100 seed weight. Also, the maximum 100-grain weigh was obtained in the sweep type weeder method (Table 3). Achievment of the highest 100-grain weight in the second cropping year in the KS-21189 with semi-determinate growth habit indicated that the this line could sue natural resources better than other lines in order to increase photosynthetic rate and enhance 100-grain weight. Also, the enhancing of 100-grain weight under the application of sweep type weeder could be due to better weed control, reduction of interplant competition for the usage of natural resources and creating suitable conditions for the growth of beans.

### 3.5 Biomass yield

In this experiment, the effects of year, cultivar, the interaction effect between year, cultivar and weeding method on bean biomass yield was significant (Table 2). The highest yield of biomass was obtained in the COS-16 line and the second cropping year. In the first cropping year, the biomass yield of Sadri variety was higher than other studied lines (Table 4). Therefore, the highest biomass yield was obtained on the COS-16 line and the second cropping year.

**Table 4. Interaction effect of year and cultivar on measured traits in bean as affected by different weed control methods**

| Year - Cultivar | | Bush Height (cm) | Pods per Bush | Biomass Yield (kg ha$^{-1}$) | Harvest Index (%) | Plant injury (%) |
|---|---|---|---|---|---|---|
| | The COS-16 line | 45.8c | 13.7[b] | 8537bc | 36.1[ab] | 10.4[b] |
| First Year | The KS-21189 line | 49.5[c] | 15.7[b] | 9672[b] | 34.4[b] | 11[ab] |
| | Sadri Variety | 71.9[a] | 23.7[a] | 7393[c] | 40.7[ab] | 13[a] |
| Second Year | The COS-16 line | 59[b] | 28[a] | 15226[a] | 34.4[b] | 7[c] |
| | The KS-21189 line | 56.1[bc] | 27.1[a] | 13912[a] | 41.7[a] | 10.7[b] |
| | Sadri Variety | 57.5[b] | 28.4[a] | 13876[a] | 42.15a | 12.4a |

Note: The mean with the same alphabets in each column do not have a significant difference in the probability level of 5% of the LSD.

The findings this study suggested that in response to unfavorable environmental conditions, the vegetative growth of Sadri cultivar decreased, but there was no significant change in its reproductive growth. The biomass yield increased by using of the sweep type. Also, the application of sweep type weedr had positive effect on the growth retardation and re-growth of weeds, improvement of growth, development of the vegetative and reproductive organs in bean plants.

### 3.6 Harvest index

The effects of year, cultivar, year-cultivar interaction, weeding method and the interaction effect between the year and weeding method on harvest index were significant (Table 2). The results showed that Sadri cultivar had the highest harvest index in the second cropping year (Table 4). The highest harvest index was observed in the second cropping year, which could be due to the favority of environmental conditions for the growth and development

of reproductive organs in the second cropping year (Table 4). Also, the application of the sweep type weeder for weed control in the second cropping year showed the highest harvest index (Table 5). Increament of harvest index in Sadri variety during the second cropping year showed that beans with indeterminate growth habit had superiority for harvest index to beans with determinate and semi-determinate growth habits. Because, eans with determinate and semi-determinate growth habits has a short growth period and produces fewer flowers and pods compaired to beans with indeterminate growth habit. In particular, adverse environmental conditions such as high temperature during flowering stage could lead to a further reduction in their harvest index which these results are consistent with results of Robinson and Wilcox (2001). However, if the favorable environmental conditions are restored for the growth of beans, cultivars with indeterminate growth habit, with the production of new flowers and pods, can improve the bean harvest index. Also, the highest harvest index and grain yield were observed by using the sweep type weeder for weed control. Thus, an increase in the harvest index can be considered as one of the reasons for grain yield enhancement by using the sweep type weeder machine to combat bean weeds.

**Table 5 Interaction effect of year and weeding method on measured traits in bean as affected by different weed control methods**

| Year and weeding method interaction | | Harvest Index (%) | Plant injury (%) |
|---|---|---|---|
| First Year | Manual Weeding | 38.2ab | 0.55d |
| | Rolling Weeder | 34.2b | 18.7a |
| | Rotary Weeder | 38.2ab | 0.7c |
| | Sweep Weeder | 37.7ab | 15.9b |
| Second Year | Manual Weeding | 35.6ab | 1.7d |
| | Rolling Weeder | 39.9ab | 17b |
| | Rotary Weeder | 40.7ab | 11.6c |
| | Sweep Weeder | 41.7a | 10c |

Note: The mean with the same alphabets in each column do not have a significant difference in the probability level of 5% of the LSD.

Other researchers have shown that the weeds reduced the harvest and yield index, the growth and development of crops and the photosynthetic assimilate, through competition for the use of natural resources (Ali et al., 2015).

### 3.7 Plant injury

The effects of year, cultivar, interaction effect between year and cultivar, weeding method, the interaction effect of the cultivar - weeding method and interaction effect of year - weeding method on the number of plant injury was significant (Table 2). The plant injury for the Sadri cultivar was higher than the KS-21189 and COS-16 lines in the first cropping season (Table 5). The highest number of damaged bushes was observed in the firast cropping year by using the rolling type weeder (Table 5).

In this study, the plant injury in Sadri variety were more than KS-21189 and COS-16 lines, which was mostly related to plant growth type (Figure 3). Bean cultivars with determinate and semi- determinate growth habits have suffered more damage from weed control machines due to the growth of their aerial parts and the occupancy of more space above the soil surface during weed control operations. Also, the least and the highest number of plant injury were obtained by using the manual weeding and rolling type weeder, respectively. Also, Amador-Ramirze et al. (2001), found that the rate of damage to bean cultivars was lower in the manual weeding. Other researchers reported that there was no reduction in the number of injured plants due to the use of a sweep type weeder (Vangessel et al., 1995). The results showed that in bean plants with runner type, the number of injured plants by weeding machines increased. Thus, the use of weeding machines for bean fields with the stand growth type, looks desirable.

### 3.8 Weeding index

The effects of the year, weeding method and interaction effect of the cultivar - weeding method on the weeding index was significant (Table 2). In this experiment, weeding index changes in different cropping years were influenced by different types of weeding machine and bean cultivars (Figure 4). In this experiment, the weeding index in the second cropping year (79.33%) had superiority to the first cropping year (71.07%).

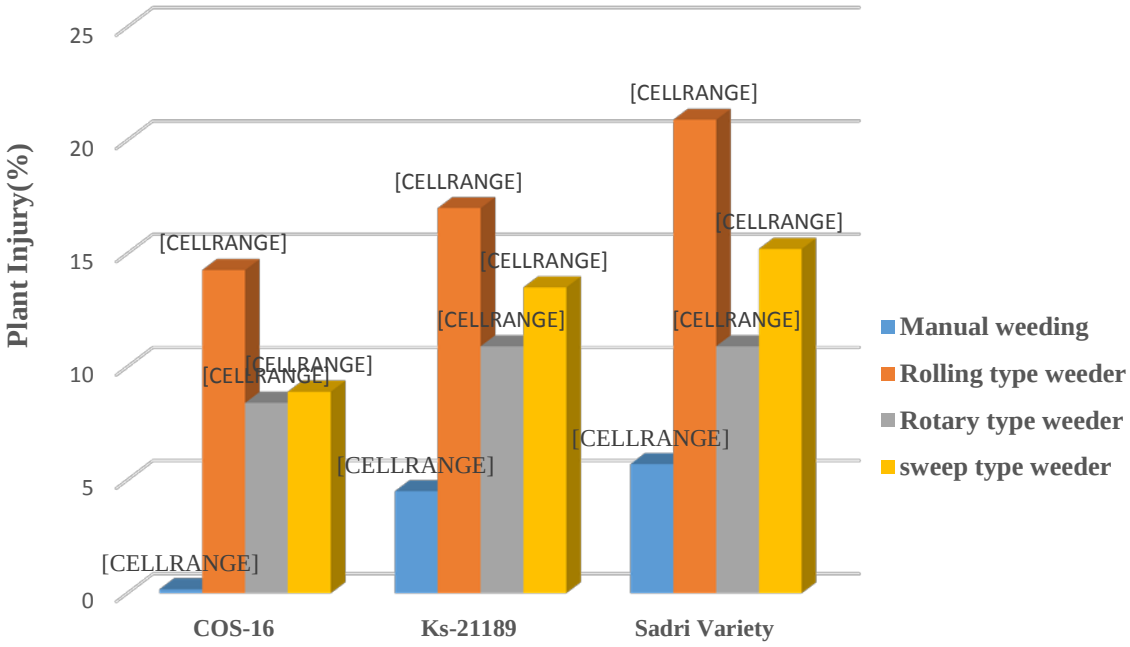



Figure 3 Interaction of cultivar and weeding method on plant injury (%)

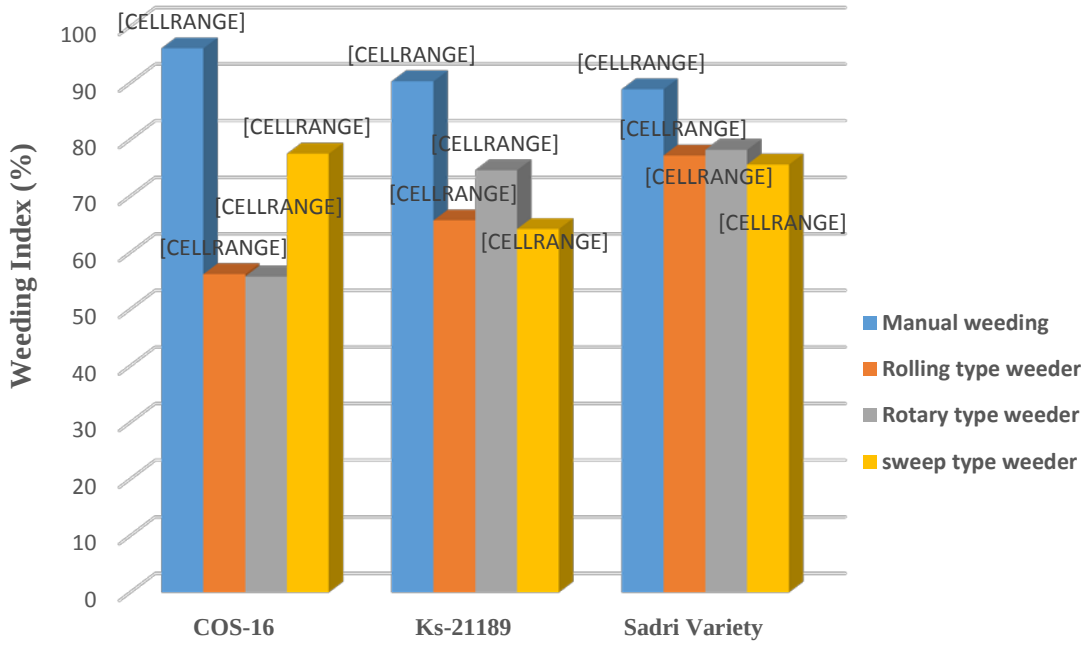



Figure 4 Interaction of variety and weeding method on weeding index (%)

The results showed that in all three studied cultivar and lines, the highest weed efficacy was allocated to the manual weeding, and the variation of weed efficacy variation influenced by the use of different weeding machines depending on the type of bean cultivars (Figure 3). Thus, in the manual weeding in spite of weeding efficiency improvement and the reducition of plant injury, yield and yield components of beans decreased in this method. The main reason for this could be the slow weeding operations in comparison to weeding machines. It seems that due to

the prolongation of weeding operations in the manual weeding, the damage caused by competition with weeds, indused water stress and reducing the photosynthetic capacity of the bean plants, reduces the yield and yield components in beans. However, by using the weeding machines, the length of the weeding operation is significantly reduced, and irrigation is done immediately after rooting the weeds, which can be considered as an important advantage.

## 4 Conclusion

In this experiment, the highest grain yield and the lowest plant injury were allocated to manual weed control method and the sweep type weeder was considered secondarily important. Therefore, the highest grain yield of beans was obtained under the usage of sweep type weeder. The hilling up the bushes of bean, the better development of sub-roots and improvement of plant growth and development can be considered as the main advantages of the sweep type weeder application and this methods of weed control could be recommended in the similar climatic conditions.

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