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Evaluation of Yield, Yield Components and Nitrate Leaching in Soybean Affected By Different Types of Fertilizers and Weed Interference

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Abstract: In recent decades, chemical fertilizers have had an adverse effect on the life cycles and sustainability of farming ecosystems. Weed interference is one of factors that reduce crop yield. To investigate effect of fertilizer types and weeds management on yield, yield components and nitrate leaching in soybean an experiment was carried out as split plot based on complete randomized block design with three replications in two years. Fertilizers types including chemical fertilizer, manure and nano-chelates spraying as the main plot and also, weed control in three levels including weeding after emergence to beginning flowering, weeding during the critical period of weed interference and no weeding were considered as sub-plots. The results showed that among the weeds control treatments, grain yield with control at critical time as well as control until flowering was achieved in a statistical group and were significantly more than non-control treatment. The highest weeds dry weight was obtained in non-weeding treatment and increase weed control time caused their weight loss. Among the fertilizer treatments, the highest dry weight of weeds was observed by chemical fertilizer use. Maximum nitrate concentration of soil at a depth of 80-100 cm were obtained by using chemical fertilizer. Weeds dry weight increased and the nitrate concentration of soil decreased when the weed control duration was reduced.

Key words: Critical period · Manure · Oil percent · Protein content · Weeds dry weight

INTRODUCTION

With regard to economic and environmental remarks, weed control does not seem to be necessary throughout the growth season,but it should be carried out at a part of the growth season of the crops (that is called critical period of weed control) to avoid excessive acceptable reduction of yield [1] .Competition for acquisition of light [2], nitrogen [3] and water [4], are considered as the main factors to cause loss of crop yield.The most important limiting factors for rapid growth of crops are nitrogen deficiency and the presence of weeds in the fields.

The yield of weed-free soybean farms during the first month after cultivation increased similarly as keeping them (farms) weed-free during the entire of growth season [5]. The dry weight of weeds is a more suitable and efficient parameter than the weeds number [6]. The most sensitive components of soybean yield to weeds are the number of seeds and pods per plant, respectively [7].

The management practices for nutrient elements can change the competition type between crops and weeds [8]. Evaluation the effect of manure and chemical fertilizers on the fodder and grain yield in intercropping millet with bean, has shown that manure is a dominant component and stronger competitor due to its positive effects on soil structure through more increase in expansion and growth of bean roots as compared with Millet roots to absorb the resources from the soil.The high yield of millet grain and fodder (on dry weight basis) when treated with 100% of chemical fertilizer has been attributed to the positive effects of macronutrient elements (nitrogen, phosphorus, potassium) on vegetative and reproductive growth of the plant and its capability for high absorption of the elements [9].

Application of organic fertilizers such as compost and manure is caused to increase organic matter and nutrient elements, improvement of soil structure and to decrease consumption of chemical inputs and consequently to increase grain yield [10]. Combined

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treatment of manure and chemical fertilizers leads to increase yield due to gradual release of the elements from manure as well as easy absorption of elements from the chemical fertilizer during the growing season [11].

Soluble nutrient spraying via roots and / or supply plant need to the elements in leaves (root and / or foliar sprayingof soluble nutrient elements) has been reported to be essential to compensate deficiency of them (the nutrient elements) especially in reproductive stage [12]. Researches has shown that foliar application of phosphorus with nitrogen and potassium is effective to improve wheat traits such as spike length, the number of grains per spike and to prevent fertilizer loss [13]. Spraying at the pollination and milky stage of wheat increased the 1000-grains weight but did not have a significant effect on grain yield [14].

At present, environmental problems caused by the use of chemical fertilizers, auxiliary energy and other production inputs over the permitted levels has had a direct impact on the life cycles and sustainability of farming ecosystems [15]. In most areas, agriculture is the main source to contamination of surface and underground waters with nitrogen [16]. Various reports have mentioned that the low use efficiency (is the best at 30-50%) [17] and high leaching (30-75%) of the chemical fertilizers are factors of concern in their use [12].The aim of the study was to evaluate the response of soybean to fertilizer application and nitrate leaching in competition with weeds.

MATERIAL AND METHODS

The experiment was carried out during two years (2016-2017) at the research farm of Islamic Azad University of Chalous (Mazandaran province) with eastern 53 degrees and 13 minutes longitude as well as northern 36 degrees and 60 minutes latitude and 9 meters height from the sea level.Chalous has a moderate and humid climate with750 mm average rainfall.

This research was carried out as split plot based on complete randomized block design with three replications.Different types of fertilizers including chemical fertilizer (urea, triple super phosphate and potassium sulfate), cattle manure (20 tons per hectare) and spraying of nitrogen, phosphorous and potassium nano-chelates were main plots, as well as weed control was sub-plot in three levels including weeding after emergence to start of flowering, weeding during the critical period of weed interference and no weeding. The critical period of weed interference with soybean was considered as 3 -7 leaf stages [18, 19].

The chemical fertilizers of nitrogen, phosphorus and potassium were used as NPK=100-50-50 per hectare based on the common usage. 50 percent of the nitrogen fertilizer was used pre-plant and the remaining at the first time of spraying (3-leaf stage). A mixture of nitrogen, phosphorus and potassium nano-chlates (with the concentration of 2 per 1000) was sprayed in three steps: three leaf stage, beginning of bloom (flowering) and beginning seed. The used cultivar of soybean was Sari.

The experimental land was fallowed before the first year of cultivation and was deeply plowed in April.The planting was performed in June. In the second year, all operations including land preparation, planting and harvesting was similar to the first year on the same land. Each experimental plot was considered to have 6 rows with the length of 3 meters,planting row space of 40 centimeters and between-row spacing of 6.5 centimeters. After crop maturity, the plants were harvested withmarginal effectconsideration in one square meter and then grain yield and yield components was determined. The protein content of seeds was measured by Bradford method [20].

At the growth season end simultaneous with the crop harvest, samples from 80-100 cm depth of the soil was obtained using augers from each of treatments to measure nitrate leaching. The nitrate concentration of soil extracts was determined by Kjeldahl method.Nitraver method was used to measure Nitrate nitrogen (NO_3) content in the soil extract.The spectrophotometer instrument (model BTS-45, made in England) was used to measure the wavelength in this method. In order to evaluate soil salinity, the soil samples were obtained from the depth of 80-100 cm andtheir saturation extracts were prepared. Then, the salinity level of the saturation extracts was measured using Conductometer instrument. SAS software version 9.3 was used for analysis of variance and the comparison of the means was done by Duncan's multiple range test at a probability level of 5%.

RESULTS AND DISCUSSION

Yield and Yield Components

Number of Pods (Per Plant): The results of combined data analysis represented that the effect of weed control on the pods number per plantwas significant at 1% probability level but, the effect of fertilizer was not significant (Table 1). The means comparison of weed control data showed that the highest number of pods per plant was obtained from the treatments of weed control during critical period and from emergence to beginning of flowering but, the lowest due to lack of weed control

Table 1: Analysis of variance and mean squares of measured treats

S.O.V	df	Pods per plant	Seed in pod	100 grain weight	grain yield	Protein content of grain	Oil percent	Weed dry weight	Nitrate leaching	Salinity
Year (Y)	1	78.916267	0.067 *	1.3601	165889.8	77.86	6.36	1.85	0.005 **	0.005
First error	4	109.402937	0.024	1.535	301191.5	15.7	2.2	283.07	0.000	0.001
Fertilizer (F)	2	462.052013	0.035**	1.487	871919.2	1366.63 *	4.31 *	55833.02 **	0.007 **	0.060 **
Y × F	2	5.48	0.000	0.001	153136.5	4.69	0.71	681.46	0.000	0.039
Seconr error	8	147.961920	0.003	2.34	554188.9	299.94	1.04	1451.38	0.000	0.001
Weeding (W)	2	427.361563 **	0.001	6.64 **	2946472.5 **	209.03	17.23 *	1858076.96 **	0.002 **	0.007
F × W	4	16.163496	0.017	2.374 *	11801.9	242.71	2.11	1924.38	0.002 **	0.006
Y × W	2	0.127756	0.000	0.001	5710.8	13.44	6.88	1.85	0.000 *	0.005
Y × F × W	4	0.009172	0.000	0.0001	11907.8	8.21	2.05	247.21	0.002 **	0.01 *
Third error	24	33.356256	0.011	0.661	67521.1	179.53	3.81	1895.67	0.000	0.003
CV (%)	-	12.74	4.93	4.46	9.15	13.21	9.44	8.98	3.12	6.73

* and ** Significant at 5% and 1% level of probability respectively

Table 2: Comparison means of measured treats

Treatment	Pods per plant	Seed in pod	100 grain weight (gr)	grain yield (kg.ha^{-1})	Protein content of grain(mg/Litr)	Oil percent	Weed dry weight (gr/m^2)	Nitrate leaching (mg/lit)	Salinity (dS/m^{-1})
Year:									
1	46.52 a	2.18 a	18.37 a	2895.3 a	102.62 a	21 a	485 a	0.33 b	0.85 a
2	44.11 a	2.11 a	18.05 a	2784.4 a	100.22 a	20.31 a	484.63 a	0.354 a	0.87 a
Fertilizer:									
Chemical	47.28 a	2.2 a	17.94 a	2951.5 a	108.51 a	20.8 ab	547.17 a	0.36 a	0.84 b
Spraying	39.56 a	2.11 b	18.51 a	2586.3 a	91.7 b	20.11 b	440 b	0.32 c	0.81 c
Cattle manure	49.1 a	2.14 b	18.17 a	2981.8 a	104.1 ab	21.06 a	467.28 b	0.35 b	0.92 a
Weeding:									
Weeding from germination until flowering Weeding	47.83 a	2.15 a	18.65 a	3107.61 a	105.36 a	20.41 ab	162.00 c	0.35 a	0.85 a
during the critical period	48.42 a	2.14 a	18.46 a	3037.56 a	99.41 a	19.83 b	487.89 b	0.35 a	0.88 a
No weeding	39.7 b	2.16 a	17.51 b	2374.44 b	99.5 a	21.74 a	804.56 a	0.33 b	0.84 a

Means within a column followed by the same letters are not significantly difference at theá=0.05 (Duncan's multiple-range test).

treatment (Table 2). To determine the critical period for velvetleaf control in summer cultivation of soybean (*Glycine max* (L.) Merr.) has been reported that the Velvetleaf interference up to the growth stages of V2 and V4 (2 and 4 foliar stages) could not significantly reduce the number of pods per plant which were attributed to the small size of soybean and velvetleaf plants in this period, sufficient availability of environmental resources for all plants and shortness of interference period and consequently the lack of a serious competition between velvetleaf and soybean. With a longer interference period of the velvetleaf with soybeans, the competition increased to a significant extent to significantly reduce the number of pods per plant as well as damage of the weed was maximized when interference be the continued to the pod development stage.The significant loss of pod numbers per plant at the interference treatments up to 6 leaf stage and afterward were caused by the reduction in plants size (their capacity for pod development) as well as leaf area index (decrease in photosynthetic compounds and thus the decrease in capability of plant to produce and maintain pods) [21].

Number of Seeds Per Pod: The effect of fertilizer on the number of seeds per pod was significant at 1% probability level while, the effect of weed control was not significant (Table 1). Based on compare means of data, the maximum number of seeds per pod was obtained via application of chemical fertilizer (Table 2). When the number of seeds per pod is determined, the suitable nutrition condition due to use of chemical fertilizer may be the cause of significant increase in this parameter.

Although the number of pods per plant and 1000-grain weight did not affected by fertilizer treatments but, the number of seeds per pod were mostly change.Practically, the final number of seeds per pod in a short period is determined at the beginning of reproductive development [21]. The loss of seeds may be

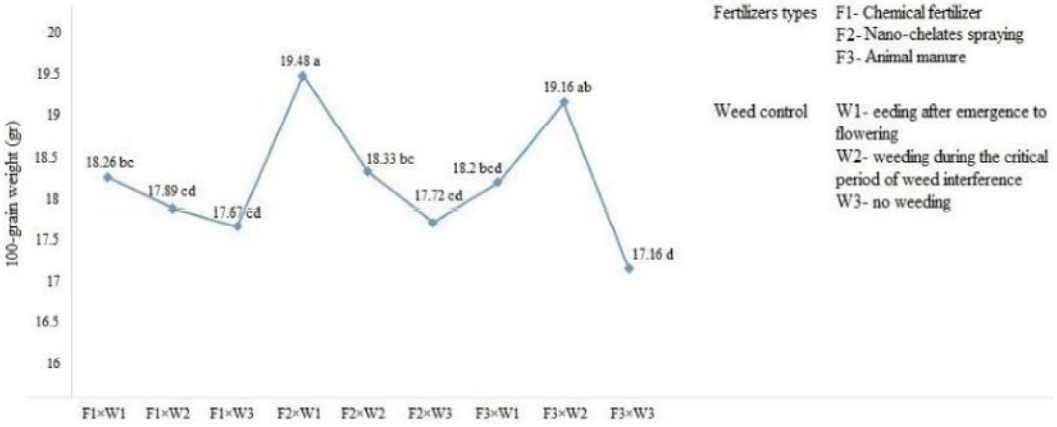

Fig. 1: Interaction of fertilizer and weed control on 100-grain weight

due to infertility, increase of abortion and / or lack of embryo evolution [22]. A larger sink is created by the increase in the number of seeds per pod to store the plant's photosynthetic products which consequently leads to increase grain yield [23].

100-Grain Weight: According to the results, 100-grain weight were significantly affected by dual treatments of fertilizer and weed control at 1% probability level (Table 1). The maximum 100-grain weight was obtained due to interaction of nano-chelate spraying and weeding from emergence time up to flowering initiation while, the minimum was obtained due to manure application and non-weeding (Figure 1).

The soybean needs to very high nitrogen at grain filling stage [24]. If one of the yield components is decreased, other components share will increase [25]. It seems that decrease in the number of pods per plant and the number of seeds per pod due to fertilizer spraying (Table 2), as well as complete control of weeds from emergence time up to flowering initiation (plant produces more photosynthetic products) and on the other hand, the fertilizer spraying at the beginning of seed stage caused more allocating of photosynthetic products to seeds and leads to better filling of them and consequently increased the size and weight of grains as compared to other treatments. The decrease in 100-grain weight due to interaction of manure and no-weed control under competitive conditions may related to the less production of photosynthetic products caused by limited availability of nutrients at the end of growth stages, inter-species competition and weed shading on the soybean plant.

Grain Yield: The grain yield was significantly affected by weed control at 1% probability level (Table 1). Although there was no significant difference between fertilizers treatments, but the trend of changes showed that the grain yield production via application of manure was more as compared to chemical fertilizer and nano-chelates spraying (Table 2). With manure and chemical fertilizer treatments, grain yield has probably increased because of higher nitrogen content.It seems that in the manure treatment, the maximum grainyield has been obtained during the entire growth period of the plant due to the gradual release of nutrients and plant access to them. Also, in chemical fertilizer treatment, nitrogen sufficiently prepared for plant as top-dress application at the right time and makes improvement of the physiological processes effective on synthesis and translocation of photosynthetic products in to the seeds which is consistent with other studies[11]. It was reported that application of nitrogen fertilizer causes to increase in 1000-grain weight and dry matter accumulation of soybean at the beginning bloom stage in limited and unlimited growth lines up to 25% and increase in grain yield of all genotypes at least 8% [26].

The yield decrease in nano-chlates spraying treatment may be due to lack of adequate nutrition of the plants which resulting in a significant reduction in the number of seeds per pod (Table 2). Anyway, nutrient spraying does not compensate basic fertilizer for plant and this method is usually used when deficiency symptoms were observed to increase the crop quality [27].

The results of this study showed that the grain yield did not significantly decreased due to weed interference up to V3 stage and after the V7 stage (3037.56 kg / ha) as

compared to control during the entire period of plant growth (1107.61 kg / Ha), but the presence of weeds during the entire period of plant growth (374.44 kg ha^{-1}) decreased the grain yield by 23.6% (Table 2).

Low yield in the treatment of non-control of weed can be due to lower leaves pruning of the plant and competition for light and nutrient [28]. The small and thin stems which are produced under these conditions have few nodes and the number of pods per node is limited which causes the plant to be weakened and yield loss [29]. In weed-free soybean farms for a month after seeding, the grain yield increases significantly similar to the farms that keeping weed-free through the growth season [5].

Qualitative Traits

Protein Content of Grain: The protein content of grain was affected by fertilizer at 5% probability level and weed control had not significant effect on it (Table 1). The highest protein content of grain was observed in the effect of chemical fertilizer application which was not significantly differed from the manure application. Nano-chelates spraying caused reduction in the seed protein content by 15.49% (Table 2).Chemical fertilizers provide nitrogen and phosphorus elements for the plant especially in the early stages of plant growth when the organic fertilizers are decomposing and resulted in better conditions for plant growth and production and finally the protein function increases. The relationship between mineral elements in soil such as nitrogen with water-soluble sugars is influenced by environmental factors, so that access to nitrogen causes it to be absorbed more by the plant, thereby cause increase in the crude protein and decrease in the sugar content. After a while, when the photosynthesis is intensified, the amount of sugars increases and protein deficiency is occurred which in the effect of organic fertilizers due to the gradual release of the elements, it is clearly more observable [11]. In artichoke, the effect of chemical and combined fertilizers on the protein percent and water-soluble carbohydrates was reported more than the effect of organic manure [30].

Seed Oil Percent: The results of combined data analysis represented that the effect of fertilizer and weed control on the percent of seed oil was significant at 5% probability level (Table 1). Maximum content of seed oil was obtained using manure. Using chemical fertilizer, this content decreased and fertilizer spraying caused to minimum percent of seed oil (Table 2). The reduction of oil percent has been reported in the effect of urea application (200 kg per hectare), while bacterial inoculation and biological fixation increased oil percent of grains [24]. At stem elongation and flowering stages of rapeseed, nitrogen spraying decreased the oil percent of seed. There was no significant difference between the spraying and common soil fertilizer treatments in terms of oil content of rapeseed [31]. Comparison of means showed that the highest percent of seed oil was observed if the presence of weeds was continuous and it was decreased due to weeding, so that the control treatments at the critical stage and continuous weed control were not significantly different (were placed in a statistical group) (Table 2). The increase of seed oil percent in non-weeding treatment may related to decrease in the seed protein content and also the negative relation between the protein content and the seed oil percent. The decrease in the seed oil content due to increase in nitrogen application as well as negative correlation between oil percent and the used nitrogen amount has been reported by another researcher [20].

Weeds Dry Weight: The results of combined data analysis state that weeds dry weight were significantly different in the effect of fertilizer and weeds control at 1% probability level (Table 1) as maximum weeds dry weight was obtained in non-weeding treatment. Weeds control in 3 - 7 foliar stage of soybean was decreased weeds dry weight. The minimum dry weight was obtained using weeding after emergence up to flowering stage Table 2). Among the fertilizer treatments, the highest weeds dry weight belonged to chemical fertilizer application and the difference between manure and nano-chelates spraying was not statistically significant (Table 2). The prolongation of weed-free period increased competition capability of soybean and thus caused to decrease in weed dry weight. It seems that prolonged weed-free period caused to increase competition capability of soybean and thus caused to decrease in weeds dry weight.

To determine the critical period for weeds control in soybean cultivation has been stated that with the increase of weeds dry matter (which is occurred with shortness of control period or longing interference period), the weed share among the effective environmental factors on growth (such as radiation, nitrogen and other nutrients) increases and the crop share decreases, inversely.

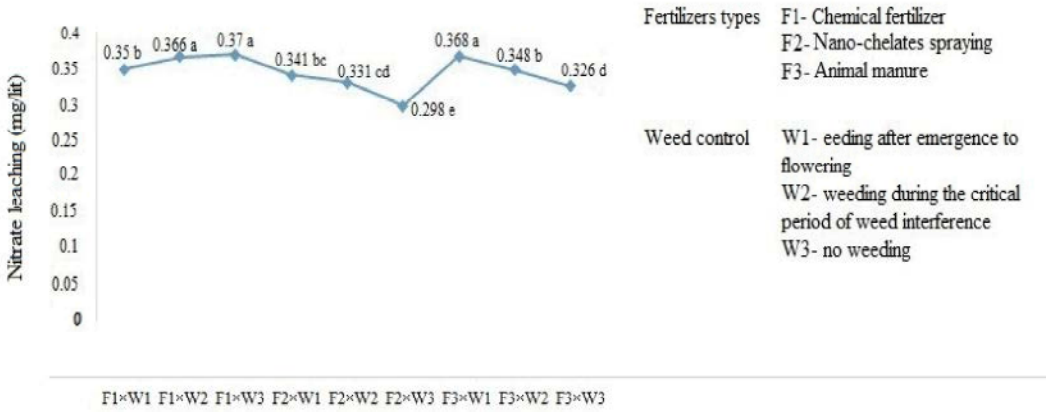

Fig. 2: Interaction of fertilizer and weed control on soil nitrate concentration

Consequently, increase in weed dry matter will usually be accompanied by decrease in dry matter and crop yields [21]. Among the fertilizer treatments, chemical fertilizers when was used, weeds that have a high adaptation to their ecosystem conditions, have been more successful to compete with soybean to absorb nutrients and have been obtained the highest dry weight. On the other hand, the dry weight of weeds due to application of manure and nono-chelates spraying was less than that of chemical fertilizers because of the gradual release of nutrients needed for weeds growth. The nutrients management can change the competition type between crops and weeds [8].

Nitrate Leaching: The results of combined analysis of variance showed that fertilizer and weeds control interaction on nitrate concentration in the soil depth of 80-100 cm wassignificant at 1% probability level (Table 1). The comparison of means related to this interaction represented that the highest nitrate concentration of soil was attained from dual application of manure and weeding up to flowering stage as well as from dual chemical fertilizer and weed control at critical period but, the lowest concentration was obtained from dual using of nano-chelates spraying and weeding (Figure 2). As would be predicted, foliar spraying of fertilizer was minimized nitrate concentration in soil because of its foliar consumption and lack of soil connection.

The highest concentration of soil nitrate was observed with dual application of manure and weeding up to flowering stage as well as, with chemical fertilizer and Weed control at critical period. The lowest nitrate concentration was obtained due to fertilizer spraying and weeding dual effects (Chart 2). As it would have predicted, foliar fertilizer spraying due to disconnection with the soil caused to the minimum concentration of nitrate in soil. Nitrate leaching during the growth period depends on the initial nitrogen of the soil, applied nitrogen, plant growth conditions,nitrogenuptake by plant and fertilizer- irrigation management [32]. The presence of nitrate due to the use of chemical fertilizers is one of the important indicators for water resources, soil and crops contaminations [33].

It seems that the high amounts entry of nitrogen due to the use of chemical fertilizer and the inability of the plant to absorb it fully at once, has caused to the nitrogen loss and its accumulation in depth of the soil. However, organic fertilizers also contain amounts of ammonium ions which is converted to the nitrate through urease enzyme activity and is produced a significant amount of nitrate that is not absorbed by soil particles due to its negative charge and so moves to the lower levels of soil profile via irrigation or precipitation and ultimately its concentration increases in the drainage water sample [34]. In addition to the use of chemical fertilizers, the accumulation of nitrate in the soil has been also reported due to livestock excreta [35].Increase in nitrogen uptake by plant leads to decrease nitrate transfer to lower layers and hence the potential for nitrate leaching decreases [33].

Soil Salinity: Based on the results of combined data analysis, salinity of soil was affected by fertilizer at 1% probability level but it was not affected by weeds control (Table 1). In the soil depth of 100 cm, the salinity was maximum using manure and it showed the reduction trend using chemical fertilizer. Nano-chelates spraying caused minimum electrical conductivity (EC) (Table 2). It seems that the manure is rich from cations and organic matter which cause to increase in cation exchange capacity of the soil.Another research finding[18], is also supported these results.

The use of compost increases the cation exchange capacity of the soil, while mineral fertilizers reduce it [33].The entry of calcium, magnesium and potassium from the leaching water into the soil causes increase in the cation exchange capacity (CEC) of the soil and thus the exchange sites are saturated with calcium, magnesium and potassium and prevent the entry of sodium into the exchangeable complex of the soil. So, the soluble form of sodium and eventually EC in the outlet drains increases [36].

CONCLUSION

The results showed that crop yield as the most important economic yield component in agriculture was not significantly affected by fertilizer but, the highest levels of nitrate leaching was observed due to application of chemical fertilizer.

Presence of weeds throughout the growth season, has caused to reduce the nitrate leaching which has an important role to prevent nitrate transfer to the groundwater and its contamination.Also, the weight of weeds decreased due to increase in weed control period. Regarding the lack of statistical difference of grain yield between weed control treatments at critical period with control from emergence to soybean flowering, it is sufficiently can be controlled weeds at the critical stage.With joint regard to the economic and environmental issues, the manure application and weeds control at critical stage can be recommended as superior treatment in this research.

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