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EFFECT OF NEEM FERTILIZER RATES AND WEED CONTROL METHODS ON THE GROWTH AND YIELD OF SOYBEANS (*Glycine max* (L.) Merrill) IN NORTH CENTRAL NIGERIA

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ABSTRACT

Two field experiments were conducted at the Research Farm of the Ibrahim Badamasi Babangida University, Lapai, Niger State during the 2018 and 2019 rainy seasons to determine the effect of neem fertilizer rates and weed control methods on the growth and yields of soybeans. The experimental treatments were made up of four neem fertilizer rates (0, 50, 100 and 150 kg ha^{-1}) and six weed control methods (pendimethalin at 1.5 kg a.i ha^{-1} followed by one hoe weeding, pendimethalin at 2.0 kg a.i. ha^{-1} followed by diuron at 1.5 kg a.i ha^{-1}, weeding once at 3 WAS, weeding twice at 3 and 6 WAS, weed free and weedy check. The experiment was a 3 × 3 factorial experiment laid out in a Randomize complete block design replicated three times. TGX 1448 – 2E variety of soybean was used for the study. Result showed that weed control efficiency was better with the use of 150 kg ha^{-1} of neem fertilizer, while decrease in weed dry matter was obtained at 50 kg ha^{-1}. Increase in number of leaves and leaf area were encouraged with 150 kg ha^{-1} of neem fertilizer. Weed free treatments recorded the highest grain yield and 100 seed weight of soybean. Pendimethalin at 1.5 or 2.0 kg a.i ha^{-1} supplemented with one hoe weeding or diuron at 1.5 kg a.i ha^{-1}respectively can be an alternative for better control of weeds to obtain greater yield of soybean in the study area.

Keywords: Soybeans, weed control, neem fertilizer, yield, pendimethalin, diuron

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INTRODUCTION

Soybean (*Glycine max* L.) is a sub-tropical plant that is adapted to tropical and temperate conditions (Udoh and Ndon, 2016). The crop is recognized as one of the most important legumes in sub-Sahara Africa (Jandong and Uguru, 2019). Hamma *et al*. (2019) reported that soybean is grown traditionally in calcareous soils in arid and semi-arid regions. Zimbabwe, Nigeria, Zambia, Zaire, Rwanda and Ethiopia are the most important countries in tropical Africa that are known for soybean production (Udoh and Ndon, 2016).

The world soybean production stood at 348,712,311 metric tons in 2018 and Brazil was the largest producer accounting for 36% (125, 887,672) of the world production, followed by United state (123,664,230t), Argentina (37,787,727t) and China (14,193,621t) (FAOSTAT, 2018). World production of soybeans is predicted to increase by 2.2% annually to 371.3 million tons by 2030 using an exponential smoothing model with a damped trend (Masuda and Goldsmith, 2009). Soybean is cultivated in an estimated global area of 108.75 million hectares with a production reaching 268 million tonnes now the world's leading oil seed crop (Changkija and Gohain, 2018)

Soybean cultivation in Nigeria has expanded as a result of its nutritive and economic importance and diverse domestic usage (Dugje *et al*., 2009). Soybean contributes approximately 40% protein and 20% fat to the body which made the crop economically important for human and animal consumption. Lambon *et al*. (2018) identify soybean as a good source for pharmaceutical and industrial uses. In addition to its use as a source of protein and oil, the crop also improves fertility of the soil by contributing to soil nitrogen through nitrogen fixation (Kureh *et al*., 2005).

It has been established that tropical soils are infertile due to continuous farming activities, grazing of animals and accelerated soil erosion among others (Garba *et al*., 2019b). Through these activities mentioned above, high percent of soil nutrients are been washed away in many small holder farmer's fields thereby reducing the available soil nutrients for plant growth and development. The effect of the use of inorganic fertilizer in crop production have always been about environmental hazards/pollution, leaching, soil degradation among others and the need to achieve a sustainable agriculture is very important. Hartmann *et al*. (2015) reported that the extensive application of synthetic fertilizers generates negative impacts on crop nutrient uptake, reduces soil quality, and causes environmental hazards. Proper fertilization is one of the major factors to gain higher yield but injudicious application of inorganic fertilizers without organic supplements causes environmental pollution, damaging soil physical, chemical and biological properties (Mamia *et al*., 2018). The incorporation of organic manure into the soil in order to augment soil structure and enhance adequate moisture for plant growth is a recommendable practice in obtaining better yield of the crops (Tabo *et al*., 2007). Neem organically formed fertilizer serves as a soil amendment and has been reported by Lokanadhan and Jeyaraman (2012) to increase soil nutrient contents such as nitrogen, phosphorus, sulphur, phosphorus, and calcium. Application of organic manure alone or in combination of chemical fertilizer will help to improve the physio-chemical properties of soils by providing a good substrate for the growth of microorganisms maintaining a favourable nutritional balance (Mamia *et al*., 2018).

Weed control is one of the major problems that farmers contend with in crop production. Weed interference is an important factor that attributes to low grain yield in soybean field. Weed-crop competition and low soil fertility in farmer's field are among the factors that attributed to poor yield of soybean (Sodangi *et al*., 2011). About 80 % yield losses of soybean has been reported in many parts of the world (Daugovish *et al*., 2003). The objective of this research is to assess the effectiveness of different fertilizer rates under different weed control methods on the growth and yield of soybean.

MATERIALS AND METHODS

Experimental site

Field experiments were conducted in 2018 and 2019 rainy seasons at the Teaching and Research Farm of Ibrahim Badamasi Babangida University, Lapai, Niger State to assess the effect of neem fertilizer and weed control methods on the growth and yield of soybean. Lapai is situated at Latitude 9° 2′N and Longitude 6° 34′E and altitude of about 1000 square meter in the Southern Guinea savanna of Nigeria. The analytical results of soil at the experimental site indicated that the soil was sandy loam in texture with an average soil pH of 6.65. The people living in the area are characterized by mixed farming systems which involve important crops such as soybean, cowpea, groundnut, Bambara groundnut, maize, guinea corn, millet, cashew, and livestock production such as rearing of cattle, sheep, goat, and some domestic poultry. The experimental field was cleared of existing vegetations, after which it was ploughed and ridged. The land was laid out into units of 3 x 3 m (9 m^2) each with four ridges, plot was separated by 1m pathways and between replicates.

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Experimental design

The treatments consisted of factorial combination of four rates of neem fertilizer (0, 50, 100 and 150 kg ha^{-1}) and six levels of weed control methods (pendimethalin at 1.5 kg a.i. ha^{-1}+ 1 hoe weeding (HW); pendimethalin at 2.0 kg a.i. ha^{-1} + Diuoro at 1.5 kg a.i ha^{-1}; weeding once at 3 weeks after sowing (WAS); weeding twice at 3 and 6 WAS; weed free at interval of 10 days and weedy check (control). The experiment was laid out in a randomized complete block design and replicated three times. The variety of soybean that was used is TGX 1448 – 2E. The crop was spaced at 30 cm intra-row and 75 cm inter-row spacing with three seeds per hole and later thinned to two plants per hole at two weeks after sowing.

Weed control methods

Herbicides and conventional weed control methods such as manual weeding was used for this study. Application of pendimethalin at the rates of 1.5 and 2.0 kg a.i. ha^{-1} was applied a day after sowing using a CP3 knapsack sprayer. Diuron is a selective post emergence herbicide and it was applied as a supplement to pendimethalin at 6 weeks after sowing (WAS). Manual weeding was conducted at a specified time during the growth period at 3 and 6 WAS, 10 days interval for weed free and weedy check for plots without weeding throughout production period.

Fertilizer application

Application of neem fertilizer was done at three weeks after sowing based on the treatments design. The neem fertilizer used for this study was industrially formulated in a granular type and it is 100 percent organic fertilizer produced by M. D. Karaye fertilizer Co. Nig. Ltd. Formula for calculating the quantity of neem fertilizer per stand is shown below;

$$\text{Quantity} = \frac{\text{Rate (kg)} \times \text{area of plot (m}^2\text{)}}{10000\ (\text{m}^2)}$$

Data collection

Data on weed parameters (weed control efficiency and weed dry matter), growth parameters (plant height, number of leaves and leaf area) and yield parameters (grain yield and 100 seed weight) were collected in the net plots at 3, 6 and 9 weeks after sowing (WAS).

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Weed control efficiency (%)

Weed control efficiency (WCE) denotes the magnitude of weed reduction due to weed control treatments. It was worked out by using the formula suggested by Mani *et al.* (1973) and expressed in percentage.

$$\text{WCE (\%)} = \frac{\text{Weed density in control plots} - \text{weed density in treated plots}}{\text{Weed density in control plots}} \times 100$$

Weed dry matter

The whole sample of fresh weeds were collected from the net plot at 12 WAS using 0.5 × 0.5 quadrat. The fresh weeds were oven dried at 70^0C until constant weight was achieved and then weighed again.

Data analysis

Data collected was analysed using GenStat Discovery 17 edition software package and significant means were compared using Duncan Multiple Range Test at 5 % significance level.

RESULTS

Analysis of soil in the experimental site at Lapai during the 2018 and 2019 rainy seasons was presented in Table 1. The soil in the experimental site was sandy loam in both years with pH value of 5.7 in 2017 and 5.6 in 2018. Organic carbon, total nitrogen and distribution of available P in the soil were low. Exchangeable base was high in respect to K^{+2} and N^{+2}. Low Ca^{+2} and medium Mg^{+2} was recorded. Cation exchange capacity (CEC) of the soil was also high (72.8 and 74.4 C mol kg-1) in 2018 and 2019 respectively.

Effect of neem fertilizer and weed control methods on weed control efficiency and weed dry matter in soybean field

Effect of neem fertilizer and weed control methods on weed control efficiency and weed dry matter in soybean field at Lapai in 2018 and 2019 rainy seasons is shown in Table 2. Results showed that weed control efficiency in both years and weed dry matter in 2018 were not affected by neem fertilizer rates, but significant ($p<0.05$) difference was observed in weed dry matter in 2019. Result indicates that neem fertilizer at the rate of 0 kg ha^{-1} recorded the highest weed dry

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matter which was statistically similar with neem fertilizer at the rate of 100 and 150 kg ha^{-1}. The lowest weed dry matter was recorded in plots applied with 100 kg ha^{-1}.

Weed control efficiency and weed dry matter were significantly ($p<0.05$) affected by weed control methods of soybeans. Weed free method recorded the highest weed control efficiency and the result was followed with use of pendimethalin at the rate of 1.5 kg a.i ha^{-1} supplemented with one hoe weeding at 6 WAS and pendimethalin at the rate of 2.0 kg a.i ha^{-1} followed by diuron at the rate of 1.5 kg ha^{-1}. The lowest weed control efficiency was revealed in plots with weedy check. Weedy check recorded the highest weed dry matter, while the lowest weed dry matter was observed with the use of pendimethalin and weed free treatments. Interaction of the two factors (neem fertilizer and weed control methods) was observed on weed control efficiency in 2018 rainy season (Table 2). The result of interaction of the two factors on weed control efficiency as presented in Table 3 showed that application of neem fertilizer at the rate of 100 kg ha^{-1}in weed free plots recorded the highest weed control efficiency, though plots applied with 0 and 150 kg ha^{-1}of neem fertilizer under weed free plots were at par. Weedy check plots recorded the lowest weed control efficiency under all the neem fertilizer rates measured in this study.

Effect of neem fertilizer and weed control methods on morphological structures of soybean

Table 4 presents plant height, number of leaves and leaf area in 2018 and 2019 as affected by neem fertilizer rates and weed control methods during the 2018 and 2019 rainy seasons. Results showed that plant height in both years and leaf area in 2018 were not significantly ($p<0.05$) affected by neem fertilizer rates. Significant difference was observed in number of leaves in both years such that, application of 150 kg ha^{-1} of neem fertilizer recorded the highest number of leaves. The result was at par with plots applied with 0 and 100 kg ha^{-1} in 2018. The least number of leaves was recorded at 50 and 0 kg ha^{-1} in 2018 and 2019 respectively. Leaf area under the influence of 150 kg ha^{-1} recorded the highest leaf area, the result was at par with reduction in the rate of neem fertilizer up to 100 and 50 kg ha^{-1}, while the least leaf area was observed in plots without Neem fertilizer (0 kg ha^{-1}).

Significant difference ($p<0.05$) was observed on the effects of weed control methods on plant height, number of leaves and leaf area. Taller plants were recorded in weed free plots in both years, though the result was at par with plots applied with pendimethalin at 2.0 kg a.i ha^{-1} supplemented with diuron at 1.5 kg a.i. ha^{-1}, including weeding once at 3 WAS and weeding

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twice at 3 and 6 WAS in 2018. The shortest plant was recorded in weedy check plots, even though, in 2019, the result was at par with pendimethalin at 1.5 kg a.i. ha^{-1} followed by one hoe weeding. Weed free plots recorded the highest number of leaves in both years and the result was at par with those results obtained when weeding was done once at 3 WAS in 2019 and weeding twice at 3 and 6 WAS in both years. The lowest number of leaves was recorded under weedy check. Weeding twice and weed free treatments statistically recorded similar highest leaf area in both years, similar result was obtained in 2019 where pendimethalin at 2.0 kg a.i $ha^{-1}$was supplemented with diuron at 1.5 kg a.i ha^{-1} under weeding once. The lowest leaf area was recorded under weedy check.

Effect of neem fertilizer and weed control methods on the yield and growth of soybean

Grain yield and 100 seed weight as affected by neem fertilizer rates and weed control during the 2018 and 2019 rainy seasons is presented on Table 5. Results indicates that grain yield and 100 seed weight was not significantly affected by neem fertilizer rates in both seasons. Significant difference ($p<0.05$) on grain yield and 100 seed weights as affected by weed control method was observed in both seasons. The result showed that the plots with weed free significantly ($p<0.05$) recorded the highest grain yield in both seasons, similar highest grain yield was recorded in 2019 in plots with weeding once and twice, though, at par with the results obtained in 2018 with pendimethalin at 1.5 kg a.i ha^{-1} supplemented with one hoe weeding and pendimethalin at 2.0 kg a.i ha^{-1} followed by diuron at 1.5 kg a.i ha^{-1} in 2019. The lowest grain yield of soybean was recorded under weedy check. In 2018, similar heaviest 100 seed weight was recorded across the treatments except weedy check plots which recorded the lightest 100 seed weight.

DISCUSSION

According to the soil analysis rating of Esu (1991) and the textural triangle, the experimental field has a soil textural class of sandy loam with an average pH of 5.65. It has low total nitrogen, available P, organic carbon. The exchangeable base (K^+ and Na^+) was high with high cation exchange capacity. The soil has a low fertility status probably due to intensification of farming activities in the study area. Similar result was obtained in the work of Garba *et al*. (2019a) whose soil analysis from the same field indicates low soil nutrient as observed in organic carbon and total nitrogen. Most dominant weed species observed during the study includes; *Cleom*

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gynandra, Cleom viscola, Senna obtusifolia, Hyptis suaveolens, Boerhavia diffusa, Euphorbia heterophylla, Leucas martinicensis, Digitaria horizontalis, Eleusine indica, Cyperus amabilis and Cyperus rotundus.

Weed emergence was minimized when 150 kg ha^{-1} of neem fertilizer was used. This result might be as a result increase in neem fertilizer application rate up to 150 kg ha^{-1} which probably stimulate the vegetative growth of the crop and lead to denser leaf canopy and subsequently suppress germination and growth of weeds. The result was similar to Sweeney *et al.* (2008) who stated that weed emergence from the indigenous seed bank did not increase with N fertilizer application. Likewise, the use of 50 kg ha^{-1} resulted in the decrease of weed dry matter. The practice of weed free methods recorded the highest weed control efficiency compared to other weed control methods. However, records also showed that all weed control methods contributed in weed dry matter reduction, except weedy check which has the highest weed dry matter. Tunku and Yahaya (2017) reported that herbicides irrespective of the doses applied and hoe weeded control resulted in lower weed dry weight than the weedy check.

Applying neem fertilizer at the rate of 150 kg ha^{-1} resulted in the increase number of leaves and leaf area of soybean, this changes lead to increase in canopy size formation for improve weed control. This result corroborates the report of Steckel and Sprague (2004) who stated that canopy cover reduced weed seeds germination and also facilitate suppression of emerging weed seedlings.

The Morphological structures (plant height, number of leaves and leaf area) of soybean responded favourably to weed free method compare to other weed control treatments. Shorter plants and minimal number of leaves and leaf area were recorded in weedy check plots. This could be as a result of the competitive ability of the weeds which affected the performance of the crop. This result agrees with the findings of Lamptey *et al*. (2015) who reported that shorter plants, minimal number of leaves and leaf area were attributed to the stress caused by weeds and their competitive ability for nutrients and other growth factors such as light, moisture and space.

The insignificant response of neem fertilizer on yield parameters of soybean could be due to adaptability and ability to fix nitrogen from the atmosphere in an infertile soil with weed – crop competition gave the crop more strength to strive comparably under different neem fertilizer rates. This result corroborates with the report of Chekanai *et al*. (2018) who stated that ecological

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capability of legumes overcomes the soil infertility hurdles where soil nutrients are not severely depleted. Changkija and Gohain (2018) also stated that Soybean has a very good adaptability towards a wide range of soils and climate. Grain yield and 100 seed weight of soybean strived better under weed free, even though, application of pendimethalin was at par in the course of weed suppression and crop yield. Keeping weed free constant throughout the production period resulted to maximum crop yield (Kolse *et al*., 2010). Peer *et al*. (2013) reported that Pendimethalin at 1.5 kg ha^{-1} and hand weeding once recorded comparable yields of soybean.

CONCLUSION

From the result of this study, it can be concluded that application of 150 kg ha^{-1} of neem fertilizer was more adequate for the growth of soybean. Weed free, which signifies keeping soybean field clean of weeds at all times performed better compared to other methods, though the method is more laborious, time consuming and cost. The practice of weed free methods attributed to long lasting weed control. Pendimethalin at the rate of 1.5 or 2.0 kg a.i. followed by one hoe weeding or diuron at 2.0 kg a.i. can be an alternative to weed free with less labour and cost. Therefore, the practice of weed free or an alternative use of pendimethalin can be recommended to farmers in the study area for better growth and yield of soybeans.

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APPENDICES

Table 1. Physical and chemical properties of soil at the experimental site at Lapai

Physical properties	2018	2019
Sand (%)	76.4	75.4
Clay (%)	11.6	12.2
Silt (%)	12.0	12.4
Textural class	Sandy Loam	Sandy Loam
Chemical properties		
pH in water (1:2)	5.7	5.6
Organic carbon (%)	4.61	4.72
Total nitrogen (%)	1.94	1.83
Available P (mg kg^{-1})	0.84	0.91
Exchangeable bases($Cmolkg^{-1}$)		
Ca	1.5	1.35
Mg	0.32	0.30
K	8.79	8.69
Na	1.87	1.96
CEC ($Cmolkg^{-1}$)	72.8	74.5

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Table 2. Neem fertilizer effects and weed control methods on weed control efficiency and weed dry matter in soybean field at Lapai during the 2018 and 2019 wet seasons

	Rate (kg a.i. ha^{-1})	Weed control efficiency 2018	Weed control efficiency 2019	Weed dry matter 2018	Weed dry matter 2019
Neem fertilizer (kg/ha)					
0		51.56	55.73b	6.286	6.001a
50		52.74	55.90b	5.838	5.267b
100		55.72	55.39b	6.212	5.697ab
150		55.26	62.42a	6.433	5.790ab
SE±		1.59	1.68	0.20	0.20
Weed control methods					
Pendimethalin	1.5 fb 1 HW	70.71b	75.74b	1.802c	1.675c
Pendimethalin fb diuoro	2.0 fb 1.5	65.22b	69.49c	1.804c	1.687c
Weeding once	3 WAP	51.48c	56.72d	11.821b	10.771b
Weeding twice	3 and 6 WAP	55.41c	60.07d	1.749c	1.659c
Weed free		80.11a	82,12a	1.083c	1.117c
Weedy check (control)		0.00d	0.00e	18.879a	17.222a
SE±		1.96	2.06	0.25	0.25
Interaction					
NF×WC		*	NS	NS	NS

Means with the same letter (s) in a treatment column are not significantly different using Duncan Multiple Range test (DMRT) at 5 % level of probability. NS=not significant at 5 % level.

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Table 3. Interaction effects of neem fertilizer and weed control methods on weed control efficiency at Lapaiduring the 2018 rainy season

	NEEM FERTILIZER (Kg)			
	0	50	100	150
WEED CONTROL METHODS				
Pendimethalin @1.5 kg a.i. ha^{-1}	72.51bcd	67.81c-f	70.41cde	72.09bcd
Pendimethalin @ 2.0 kg a.i. ha^{-1} fb diuron @ 1.5 kg a.i ha^{-1}	72.69bcd	61.98d-g	58.79efg	67.42c-f
Weeding once	41.56i	53.12ghi	57.02fg	54.22gh
Weeding twice	42.97hi	62.40d-g	62.62d-g	53.65gh
Weed free	79.66abc	71.14cde	88.50a	84.16ab
Weedy check (control)	0.00j	0.00j	0.00j	0.00J
SE±		3.912		

Means with the same letter (s) are not significantly different at 5 % level of probability using Duncan Multiple Range test (DMRT).

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Table 4. Neem fertilizer effects and weed control methods on morphological structures of soybean at Lapai during the 2018 and 2019 wet seasons

	Rate (Kg a.i. ha^{-1})	Plant height 2018	Plant height 2019	Number of leaves 2018	Number of leaves 2019	Leaf area 2018	Leaf area 2019
Neem fertilizer (kg)							
0		33.85	35.18	66.22ab	66.06c	24.45	17.95b
50		34.16	35.78	61.94b	68.28bc	22.59	21.15ab
100		35.82	35.77	65.72ab	79.28bc	23.75	19.54ab
150		34.36	36.58	76.72a	85.28a	23.92	21.79a
Se±		1.00	1.13	3.86	4.10	0.98	1.12
Weed control methods							
Pendimethalin	1.5 fb 1 HW	33.68b	32.06c	65.50bc	63.83cd	25.62a	18.88ab
Pendimethalin fb diuoro	2.0 fb 1.5	35.34ab	337.14b	63.67bc	72.92bc	22.03b	21.50a
Weeding once	3 WAP	34.04ab	36.39b	64.58bc	86.17ab	21.30b	19.76a
Weeding twice	3 and 6 WAP	37.35ab	35.95bc	75.67ab	79.50ab	26.77a	22.19a
Weed free		37.82a	41.49a	84.33a	92.17a	28.86a	22.88a
Weedy check (control)		29.06c	32.00c	52.17c	53.75d	17.50c	15.42b
Se±		1.22	1.38	4.72	5.02	1.20	1.37
Interaction							
NF ×WC		NS	NS	NS	NS	NS	NS

Means with the same letter (s) in a treatment column are not significantly different using Duncan Multiple Range test (DMRT) at 5 % level of probability. NS=not significant at 5 % level

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Table 5. Neem fertilizer effects and weeds control methods on yield parameters of soybean at Lapai during the 2018 and 2019 wet seasons

	Rate (Kg a.i. ha^{-1})	Grain yield (kh/ha) 2018	Grain yield (kg/ha) 2019	100 seed weight (g) 2018	100 seed weight (g) 2019
Neem fertilizer (kg)					
0		888.9	651.9	11.87	12.41
50		733.3	851.9	11.74	13.02
100		755.6	859.3	11.67	13.07
150		792.6	740.7	11.58	13.01
Se±		119.3	76.2	0.16	0.22
Weed control methods					
Pendimethalin	1.5 fb 1 HW	944.4ab	566.76bc	11.95a	12.80
Pendimethalin fb diuoro	2.0 fb 1.5	744.4bc	822.2ab	11.73a	13.09
Weeding once	3 WAP	555.6bc	944.4a	11.67a	12.92
Weeding twice	3 and 6 WAP	844.4abc	922.2a	11.86a	12.62
Weed free		1200a	1044.4a	12.04a	13.32
Weedy check (control)		466.7c	355.6c	11.05b	12.50
Se±		146.1	93.3	0.19	0.27
Interaction					
NF ×WC		NS	NS	NS	NS

Means with the same letter (s) in a treatment column are not significantly different using Duncan Multiple Range test (DMRT) at 5 % level of probability. NS=not significant at 5 % level