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Original Research Article

Row spacing and weed management methods influences growth and yield of soybean (*Glycine max* (L.) Merr.)

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Abstract

Weed infestation is among the primary reasons for low yields of soybean in Nigeria and other parts of Sub Saharan Africa (SSA). Field trials were therefore carried out in 2016 and 2017 cropping seasons to evaluate the effect of row spacing and weed management methods on growth and yield of soybean. The use of 50 cm row spacing resulted in significant (P < 0.05) reduction in weed cover score, weed density and weed dry matter with subsequent increase in soybean growth and grain yield compared to 75 and 100 cm row spacings in both years. In addition, early weed control with probaben at 2.0 kg a.i (active ingredient) ha[1] followed by (fb) supplementary hoe weeding (shw) at 6 weeks after sowing (WAS) suppressed weeds and increased soybean growth, which carried through to final dry matter and yield. Pre-emergence application of Probaben fb shw at 6 WAS gave the best weed control and resulted in significantly (P < 0.05) higher soybean grain yield compared to two and three hoe weedings or sole application of probaben under 50 and 75 cm inter-row spacing. However, three hoe weedings gave the best weed control and grain yield under 100 cm inter-row spacing. These results suggest that narrow row spacing of 50 cm and weed control by pre-emergence application of probaben fb shw will improve the productivity of soybean. Wide row spacing, however, required longer weed-free period and consequently multiple hoe weeding for optimum soybean yield.

Keyword: Soybean; weed management; row spacing; hoe weeding; propaben

INTRODUCTION

Soybean (*Glycine max* (L.) Merr.) is one of the most important grain legume and oilseed crops in the world. It accounts for more than 50% of the global oilseed production, and is a cheap source of protein in Sub Saharan Africa (SSA); see Kolapo (2011) and Joubert and Jooste (2013). In addition, soybean fixes about 44–103 kg ha^{-1} of atmospheric nitrogen per year, for its own use and the benefit of intercropped cereals and subsequent crops in rotation (Sanginga et al., 2003). This makes it an important crop for soil fertility improvement especially for smallholder farmers who are often unable to afford synthetic nitrogen fertilizers. Soybean is grown on 1.5 million ha annually in SSA where it serves as a major crop for food and nutrition security of millions of rural and urban dwellers (Khojely et al., 2018).

Nigeria is the second largest producer of soybean after South Africa in SSA, with larger percentage grown mainly by smallholder farmers (Khojely et al., 2018). However, the country currently produces only 25% (550,000 tonnes) of its annual soybeans requirement (2.2 million metric tonnes), leaving a supply gap of 1.65 million tonnes (75%) (FAO, 2014). To bridge the wide gap between supply and demand of soybean, Nigeria resorted into importation of soybean and soybean oil. Between 2013 and 2016, SSA countries spent about 4.4 billion USD on soybean importation with Nigeria accounting for over 21% of the total import volume (Abate et al., 2012; Rusike et al., 2013). This situation has been attributed to the poor yield obtained by farmers in Nigeria. Average soybean yield in Nigeria is about 960 kg $^{-1}$ way below the world average of 2.4 t ha^{-1} (Khojely et al., 2018) and potential yield of 3 t ha^{-1} obtained from research trials in Nigeria (Tefera, 2011). Among the factors attributed for the poor yield of soybean in SSA, weed infestation appears to be the most deleterious, causing an average reduction of 37% while other pests and diseases account for 22% (Oerke and Dehne, 2004). In Nigeria, between 77 and 90% reduction in potential soybean yield was reported from different zones due to weed infestation, while infestation of soybean field by weeds such as *Imperata cylindrica*, *Rottboellia cochinchinensis*, *Cynodon dactylon*, *Cyperus* spp., *Euphorbia heterophylla* and host of others could lead to total yield loss if not controlled (Sodangi et al., 2006; Imoloame, 2014).

Hoe weeding is the predominant weed management technique commonly used by farmers in Nigeria. However, this method is tedious, inefficient and extremely expensive, taking around 40 to 60% of the total production cost (Adigun and Lagoke, 2003; Imoloame, 2014). Aside the high cost, availability of labour for weeding is uncertain especially during critical periods of weed control, resulting in delayed weeding, well after the crops have suffered irrevocable damage from weeds (Adigun, 2005; Chikoye et al., 2007). Alternatively, herbicide use is an efficient, fast and effective method of weed control. It reduces drudgery and protects crops from early weed competition (Gesimba and Langat, 2005). However, most available herbicides do not give full-season weed control and there is hardly any herbicide that can control different kinds of weeds with one or two applications (Chauhan and Opena, 2013). In addition, the high cost of herbicides for smallholder farmers, coupled with phytotoxicity that might be induced at high rate of herbicides application as well as its residual effect have made the additional use of post-emergence herbicide for control of late emerging weeds less desirable. Furthermore, uncontrolled use of herbicides may result in increased herbicide-resistant weeds, shifts in weed species population and environmental pollution (Geier, 2006; Powles and Yu, 2010). A change in outlook from weed control to weed management is thus needed to adequately address the problems posed by weeds in soybean production. Weed management involves the integration of knowledge and techniques that minimizes weed emergence and interference with the crop (Buhler et al., 1999; Osipitan, 2013). Combining cultural management techniques with reduced frequency of hoe weeding and herbicide use will reduce weed interference and sole reliance on herbicides or on labour. There is an increased interest in the use of cultural techniques in integrated weed management systems (Chauhan et al., 2010; Adigun et al., 2017). One approach is to modify the agronomic practices to enhance the ability of crops to compete with weeds (Bhagirath et al., 2013). Among agronomic practices, row spacing is of immense significance, because it influences weed dynamics, weed-crop interference and crop competitiveness with weed (Gricher et al., 2004; Cox and Cherney 2011) and therefore will affect weed management. There is paucity of literature, however, on the combined effect of row spacing and weed management methods in soybean systems. To our knowledge, no study has addressed this subject in South Western Nigerian conditions. We hypothesized that efficient weed management and optimum yield in soybean can be achieved through narrow row spacing and integrated weed control. Therefore, the aim of this study was to evaluate the effect of row spacing and weed management methods on weed infestation and growth and yield of soybean.

MATERIAL AND METHODS

Site description

Field experiments were carried out at the Federal University of Agriculture, Abeokuta, Nigeria (7° 15′ N, 3° 23′ E 159 m above sea level) during 2016 and 2017 late cropping seasons (July–December). Abeokuta is located in the forest savannah transition zone of South-Western Nigeria and characterized by bimodal pattern of rainfall with mean annual rainfall of 1000 mm. The site received a total rainfall of 669.6 and 544.6 mm throughout the period of crop growth in 2016 and 2017, respectively (Table 1). The mean monthly temperature ranged from a minimum of 22.5 and 21.1 °C to a maximum of 28.9 and 29.1 °C in 2016 and 2017, respectively (Table 1). The soils of the fields in both years had a sandy texture, pH of 7.7 and 7.5; organic matter of 2.5 and 2.1% and nitrogen of 0.25 and 0.21% in 2016 and 2017, respectively.

Treatment details

The experiments in both years had three row spacings (50, 75 and 100 cm) all at intra-row spacing of 10 cm as the main plots treatments, and three weed management methods and weedy check as the sub-plots treatments. All the treatments were arranged in a split-plot design with three replications. The gross and net plot sizes in both years were 4.5 m×3.0 m and 3.0 m×3.0 m, respectively. The sub-plots treatments (weed management methods) included:

- Probaben at 2.0 kg a.i. (active ingredient) ha^{-1};
- Probaben at 2.0 kg a.i. ha^{-1} followed by (fb) supplementary hoe weeding (shw) at 6 weeks after sowing (WAS);
- Three hoe weedings at 3, 6 and 9 WAS;
- Weedy check.

Semi-determinate, late maturing, high yielding soybean (var. 1448-2E) seeds recommended for South-Western Nigeria agro-ecological zone were sown manually in both years. Herbicide treatments were applied pre-emergence, one day after sowing with knapsack sprayer (CP 15, Hozwlock-Excel, Cedex, France) with spraying volume of 250 L ha^{-1} using deflector nozzle at a pressure of 2.1 kg cm^{-2}. Hoe weeding was done using West African hoe in both years.

Weed observations

Data on weed cover score, weed density and weed dry matter were collected periodically at 6, 9 and 12 WAS in both years using a 50 cm × 50 cm quadrat placed

Table 1. Meteorological data during the experiment in 2016 and 2017 at Abeokuta

Month	Total rainfall (mm)		Relative Humidity (%)		Temperature (°C)			
					Maximum		Minimum	
	2016	2017	2016	2017	2016	2017	2016	2017
June	150.5	111.0	72.0	80.8	30.6	30.4	22.7	23.0
July	65.2	156.0	72.7	85.5	29.7	29.1	23.0	22.2
August	63.6	90.0	72.8	81.0	28.9	28.3	22.7	22.7
September	229.0	52.0	68.9	77.3	30.5	29.0	23.6	21.4
October	155.4	90.0	65.3	82.2	32.3	32.0	22.6	23.1
November	5.9	45.6	65.3	75.5	32.7	34.1	23.5	23.0
December	0.0	0.0	56.6	77.3	35.3	33.7	22.5	21.1
Total	**669.6**	**544.6**						

Source: Department of Agro Meteorology and Water Resources Management, University of Agriculture Abeokuta, Ogun State.

Table 2. Relative abundance of common weed species at the experimental sites in 2016 and 2017

Weed species	Plant family	Level of infestation	
		2016	2017
Broad leaf weeds			
Tridax procumbens **(Linn).**	**Asteraceae**	***	***
Euphorbia heterophylla **(Linn).**	**Euphorbiaceae**	***	***
Commelina benghalensis **(Burn.)**	**Commelinaceae**	***	***
Gomphrena celozoides **(Mart.)**	**Amaranthaceae**	***	***
Spigelia anthelmia **(Linn).**	**Loganiaceae**	–	**
Boerhavia diffusa **(Linn).**	**Nyctaginaceae**	–	**
Chromoleana odorata (**L.) R.M. King and Robinson**	**Asteraceae**	*	**
Grasses			
Digitaria horizontalis **(Willd.)**	Poaceae	**	***
Panicum maximum **(Jacq)**	Poaceae	***	***
Axonopus compressors **(Sw.) P. Beauv**	Poaceae	**	**
Eleusine indica **(Gaertn)**	Poaceae	**	**
Rottboellia conchinchinensis **(Lour.) Clayton**	Poaceae	–	**
Cynodon dactylon (L) **Gaertn**	Poaceae	***	***
Sedge			
Cyperus rotundus	Cyperaceae	**	**

*** Highly infested (60–90%)
** Moderately infested (30–59%)
* Low infestation (1–29%)
– not noticeable

randomly at three spots in each plot. Weeds sampled from the quadrat were counted and oven dried at 70 °C for 72 hours, after which they were weighed and expressed in g m^{-2}. Weed cover score was accessed by visual estimate based on a scale 0–100%: where 0 represents no weed and 100 complete weed cover (Kercher et al., 2003; Tunku et al., 2007; Nikoa et al., 2015).

Soybean growth and yield observations and measurement

Observation on soybean growth parameters such as plant height (cm plant^{-1}), number leaves, leaf area, crop dry matter and number of root nodules were recorded per metre square within the net plot at three weeks intervals in both years. The leaf area per plant was calculated following the procedure outlined by Wiersma and Bailey (1975) using the derived equation: $A = 0.411 + 2.00\ LW$, where A is leaf area and L and W are the length and width of the terminal leaflet of a fully expanded trifoliate leaf, respectively. Soybean canopy cover was determined from photographed plot pictures taken from a height of 1 m at 6, 9 and 12 WAS using a smart Tablet, and each image was converted to canopy cover (%) with the Canopeo application (Oklahoma State University, http://canopeoapp.com/). The yield attributes such as number of pods and pod weight were recorded per metre square within the net plot of each treatment. The seed yield of soybean was obtained after threshing the plants in each plot.

Table 3. Effect of row spacing and weed management methods on weed cover score in soybean in 2016 and 2017

Treatments	Weed cover score (%)					
	6WAS		9WAS		12WAS	
	2016	2017	2016	2017	2016	2017
Row spacing (RS) (cm)						
50	20c	25c	18c	22c	15c	17c
75	26b	33b	37b	43b	47b	53b
100	32a	37a	46a	53a	61a	66a
LSD (5%)	0.9	1.2	1.3	1.5	1.5	1.7
Weed management methods (WM)						
Probaben	23c	26c	36b	44b	49b	55b
Probaben + shw at 6 WAS	19d	24d	15d	22d	8d	11d
3 Hoe weedings	27b	30b	29c	33c	37c	42c
Weedy check	35a	44a	54a	59a	70a	74a
LSD (5%)	1.1	1.4	1.5	1.7	1.7	1.9
RS × WM ($P \leq 0.05$)	2.1 ns	2.9 ns	3.1 ns	3.6 ns	3.8 ns	3.9 ns

WAS – weeks after sowing, shw – supplementary hoe weeding, LSD – Least significant difference, ns – not significant at $P < 0.05$
Means labelled with the same letter do not differ significantly from one another ($P = 0.05$)

Table 4. Effect of row spacing and weed management methods on weed density and weed dry matter in soybean in 2016 and 2017

	Weed density (g m^{-2})						Weed dry matter (g m^{-2})					
	6WAS		9WAS		12WAS		6WAS		9WAS		12WAS	
Treatments	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Row spacing (RS) (cm)												
50	20.4c	22.3c	22.1c	24.4c	22.6c	27.0c	34.3c	39.9c	25.4c	29.6c	32.2c	49.1c
75	28.3b	31.2b	32.4b	35.2b	34.6b	41.4b	65.9b	71.5b	50.9b	50.4b	55.0b	57.3b
100	38.8a	43.4a	43.2a	47.3a	47.1a	53.2a	76.8a	82.6a	80.8a	83.7a	75.2a	81.5a
LSD (5%)	2.9	2.8	3.1	3.2	2.9	3.9	3.3	3.5	3.1	3.6	3.4	3.9
Weed management methods (WM)												
Probaben	19.3c	22.0c	38.2b	41.2b	43.7a	43.0b	49.0c	52.0c	55.0b	55.3b	48.8b	60.2b
Probaben + shw at 6 WAS	20.2c	23.2c	14.1d	17.6d	23.8c	20.2d	49.8c	52.2c	24.8d	29.4d	38.7c	40.7d
3 Hoe weedings	27.6b	30.2b	19.5c	22.5c	27.7b	30.3c	59.2b	66.2b	34.7c	39.5c	31.8d	49.7c
Weedy check	50.4a	53.3a	58.5a	61.0a	43.8a	68.5a	77.9a	88.4a	95.0a	94.0a	110.5a	100.1a
LSD (5%)	3.3	3.3	3.6	3.7	3.2	4.5	4.9	5.8	4.3	5.0	5.3	6.1
RS × WM ($P \leq 0.05$)	5.7 ns	5.6 ns	6.2 ns	6.3 ns	6.9 ns	7.3 ns	8.4 ns	9.2 ns	9.0 ns	10.7 ns	8.4	9.3

WAS – weeks after sowing, shw – supplementary hoe weeding, LSD - Least significant difference, ns – not significant at ($P < 0.05$),
Means labelled with the same letter do not differ significantly from one another ($P = 0.05$)

The resulting seed weight, in kg plot^{-1} at 12.5 % moisture content was expressed in kg ha^{-1}. Harvest index was calculated by following the procedure of Beadle (1987) as follows: Harvest index = (economic yield/biological yield) × 100.

Statistical analysis

Data collected were subjected to analysis of variance (ANOVA) using GENSTAT discovery package to determine the level of significance of the treatments. Treatment means were separated using the least significant difference (LSD at $P \leq 0.05$). The effect of year was not significant for all the parameters measured. Hence, the years were not compared with each other.

RESULTS

Effect of soybean row spacing and weed management methods on weed cover score, weed density and weed dry matter in 2016 and 2017

The experimental fields in both years were heavily infested with weeds such as *Tridax procumbens*, *Euphorbia heterophylla, Commelina benghalensis, Gomphrena celozoides, Digitaria horizontalis, Panicum maximum* and *Cynodon dactylon. Eleusine indica, Rottboellia conchinchinensis, Cyperus rotundus. Chromoleana odorata* and *Axonopus compressors* were other weed species with moderate to low infestation during both years (Table 2).

Soybean row spacing and weed management methods had significant effect on weed cover score,

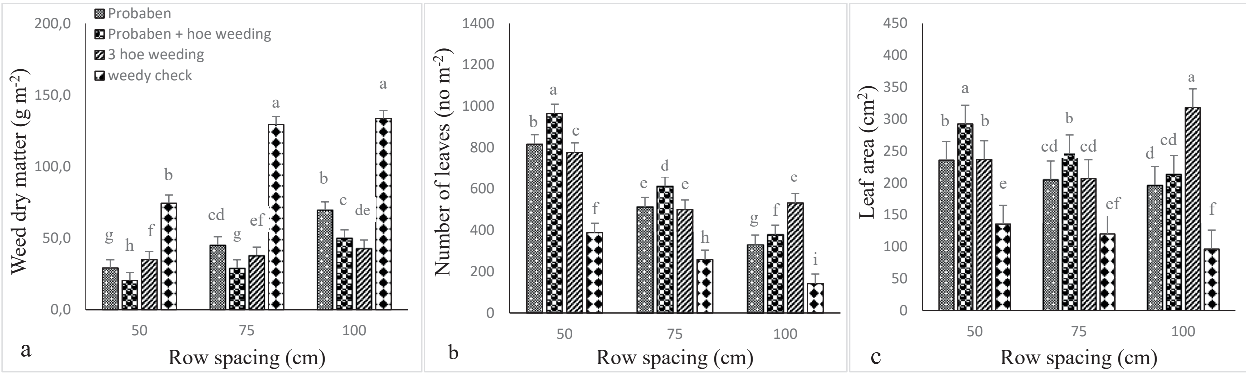

Figure 1. Interactions effects of row spacing and weed management methods on weed dry matter (a), number of leaves (b) and leaf area (c) of soybean at 12 WAS.
Means represent 2-year average. The columns denote means ± standard error; means labelled with the same case letter do not differ significantly from one another ($P = 0.05$).

Table 5. Effect of row spacing and weed management methods on soybean canopy (%) in 2016 and 2017

	Soybean canopy cover (%)					
	6WAS		9WAS		12WAS	
	2016	2017	2016	2017	2016	2017
Row spacing (cm)						
50	71a	76a	85a	89a	94a	98a
75	52b	58b	67b	73b	80b	88b
100	38c	46c	52c	58c	64c	72c
LSD (5%)	1.7	2.1	2.2	2.4	2.3	2.5
Weed management						
Probaben	58b	65b	73b	78b	79b	86b
Probaben +shw at 6 WAS	68a	73a	77a	83a	88a	94a
3 hoe weeding	46c	53c	65c	70c	77b	84b
Weedy check	42d	48d	59d	63d	71c	78c
LSD (5%)	1.8	2.3	2.4	2.6	2.5	2.7
RS × WM ($P \leq 0.05$)	3.5ns	4.3ns	4.8ns	6.5ns	8.3ns	8.6ns

WAS – weeks after sowing, shw – supplementary hoe weeding, LSD – Least significant difference, ns – not significant at $P < 0.05$
Means labelled with the same letter do not differ significantly from one another ($P = 0.05$)

Table 6. Effect of row spacing and weed management methods on plant height and number of leaves of soybean in 2016 and 2017

	Plant height (cm)						Number of leaves m^{-2}					
	6WAS		9WAS		12WAS		6WAS		9WAS		12WAS	
Treatments	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Row spacing (RS) (cm)												
50	42.0a	38.7a	74.4a	72.9a	84.1a	83.6a	242.0a	239.0a	406.0a	388.0a	750.0a	722.0a
75	40.7a	37.9a	68.5a	69.5a	76.5b	77.1b	147.3b	140.4b	249.3b	223.8b	483.1b	461.8b
100	27.3b	25.4b	61.9b	60.2b	66.2c	65.3c	99.2c	85.2c	165.7c	162.2c	367.5c	334.8c
LSD (5%)	2.2	2.0	5.2	4.8	5.1	4.7	13.3	11.8	9.6	15.8	24.0	22.0
Weed management methods (WM)												
Probaben	42.0a	40.7a	73.4b	71.6b	82.1b	79.8b	190.8a	183.9a	251.1c	230.4c	568.2c	538.6c
Probaben + shw at 6 WAS	41.9a	41.4a	82.3a	84.5a	87.5a	89.0a	189.7a	180.4a	387.7a	365.9a	668.6a	648.1a
3 Hoe weedings	34.1b	29.6b	71.3b	70.7b	81.1b	82.5b	156.4b	145.7b	271.7b	263.1b	615.2b	594.9b
Weedy check	28.6c	24.4c	46.0c	42.6c	51.6c	49.7c	114.4c	109.4c	184.2d	172.6d	282.1d	243.3d
LSD (5%)	2.6	2.5	5.7	5.4	5.8	5.4	15.4	13.4	11.3	36.7	27.8	25.9
RS × WM ($P \leq 0.05$)	4.5 ns	4.4 ns	10.0 ns	9.7 ns	10.8 ns	9.6ns	26.7 ns	23.7 ns	19.3 ns	31.6 ns	48.1	44.1

WAS – weeks after sowing, shw – supplementary hoe weeding, LSD - Least significant difference, ns – not significant at $P < 0.05$
Means labelled with the same letter do not differ significantly from one another ($P = 0.05$)

weed density and weed dry matter in both years. Interactive effects of row spacing and weed control methods were not significant for weed density at 6, 9 and 12 WAS and for weed dry matter at 6 and 9 WAS in both years, and therefore the effects of main factors are presented (Table 3). However, the interaction effects of row spacing and weed management methods were significant for weed dry matter at 12 WAS (Figure 1a) and cumulative weed dry matter in both years (Figure 2a). Weed cover score, weed density and weed dry matter (Tables 3 and 4) increased significantly with increasing soybean row spacing from 50 to 75 and 100 cm in both years. Weeds in soybean growing in 75 and 100 cm rows had 39–102 % greater density and 37–192 % greater weed dry matter (data averaged for both years) than weeds in soybean growing in 50 cm row spacing. Similarly, weed density and weed dry matter in 100 cm row spaced plots was 32–38 and 16–64%, respectively, greater than in 75 cm row spacing in both years (Table 4).

All the weed management methods significantly reduced weed cover score, weed density and weed dry matter compared to the weedy check in both years (Tables 3 and 4). Probaben applied at 2.0 kg a.i. ha^{-1} significantly reduced weed cover score, weed density and weed dry matter than hoe weeding treatment at 6 WAS. The lowest weed density at 6 WAS (from a range of 19.3 to 20.2 plants m^{-2} in 2016 and 22.0 to 23.2 plants m^{-2} in 2017) and weed dry matter (from a range of 49.0 to 49.8 g m^{-2} in 2016 and 52.0 to 52.2 g m^{-2} in 2017) was recorded in plots treated with probaben at 2.0 kg a.i. ha^{-1} compared with weed density (from a range of 27.6 to 30.2 plants m^{-2}) and weed dry matter (from a range of 59.2 to 66.2 g m^{-2}) recorded in hoe-weeded plots in both years (Table 4). However, at 9 and 12 WAS (3 to 6 weeks after supplementary hoe weeding), three hoe weeding treatments significantly reduced weed density and weed dry matter than pre-emergence application of probaben alone at 2.0 kg a.i. ha^{-1} in both years. On the other hand, at these periods, pre-emergence application of probaben at 2.0 kg a.i. ha^{-1} fb shw at 6 WAS significantly reduced weed density and weed dry matter than three hoe weedings or propaben applied alone (Table 4).

Row spacing and weed management methods interacted significantly on weed dry matter at 12 WAS (Figure 1a) and cumulative weed dry matter (Figure 2a) in both years. Lowest weed dry matter at 12 WAS (20.3 g m^{-2}) and cumulative weed dry matter (1.3 t ha^{-1}) was recorded in plots planted at 50 cm row spacing and treated with probaben at 2.0 kg a.i. ha^{-1} fb shw at 6 WAS. Highest weed dry matter at 12 WAS (from a range of 129.3 to 133.5 g m^{-2}) was recorded in plots planted at 75 and 100 cm row spacings and kept weed-infested throughout the crop life cycle (weedy check). Similarly, highest cumulative weed dry matter (7.5 t ha^{-1}) was recorded in plots planted at 100 cm row spacing and kept weed-infested throughout the crop life cycle (Figure 2a).

With 50 or 75 cm row spacing, probaben applied at 2.0 kg a.i. ha^{-1} fb shw at 6 WAS resulted in significantly lower cumulative weed dry matter than three hoe weedings or probaben applied alone. Conversely, with the use of 100 cm row spacing, three hoe weedings gave significantly lower weed dry matter at 12 WAS (Figure 1a) and cumulative weed dry matter (Figure 2a) than pre-emergence application of probaben at 2.0 kg a.i. ha^{-1} alone or fb shw at 6 WAS.

Effect of row spacing and weed control methods on soybean growth parameters in 2016 and 2017

The effect of row spacing and weed management methods was significant on soybean growth parameters in both years. Interactive effect of row spacing and weed management methods was not significant for soybean growth parameters except for number of leaves and leaf area at 12 WAS (Tables 5 to 9). Plant height, number of leaves, leaf area, crop dry matter and number of root nodules increased significantly with reduction in row spacing from 100 to 75 and 50 cm in both years (Tables 5 to 9).

All the weed management methods resulted in significantly higher crop growth compared to the weedy check as reflected in the plant height, number of leaves, leaf area, crop dry matter and number of root nodules in both years (Tables 5 to 9). Except for leaf area at 12 WAS, pre-emergence application of probaben at 2.0 kg a.i. ha^{-1} plus hoe weeding caused significant increase in all the growth indicators than three hoe weedings or probaben applied alone in both years (Tables 5 to 9). At 12 WAS, three hoe weedings resulted in significantly higher number of leaves than probaben applied alone in both years (Table 7). Probaben applied alone and hoe weeding resulted in comparable plant height at 9 and 12 WAS in both years (Table 6). Similarly, these treatments resulted in comparable number of root nodules at 9 WAS in both years. However, at 12 WAS in both years, three hoe weedings resulted in significantly higher leaf area, crop dry matter and number of root nodules than probaben applied alone (Tables 7 and 8).

Furthermore, row spacing and weed management methods interacted significantly on number of leaves and leaf area of soybean at 12 WAS in both years (Figure 1b and 1c). During this period, highest number of leaves was obtained in plots planted at 50 cm row spacing and treated with probaben at 2.0 kg a.i. ha^{-1} fb shw at 6 WAS, while the lowest number of leaves was obtained in plots planted at 100 cm row spacing and kept weed-infested throughout the crop life cycle (Figure 1b). Highest leaf area was recorded in plots planted at 50 cm row spacing and treated with probaben at 2.0 kg a.i. ha^{-1} fb shw at 6 WAS and those planted at 100 cm row spacing hoe weeded thrice. Highest number of leaves and leaf area for soybean planted

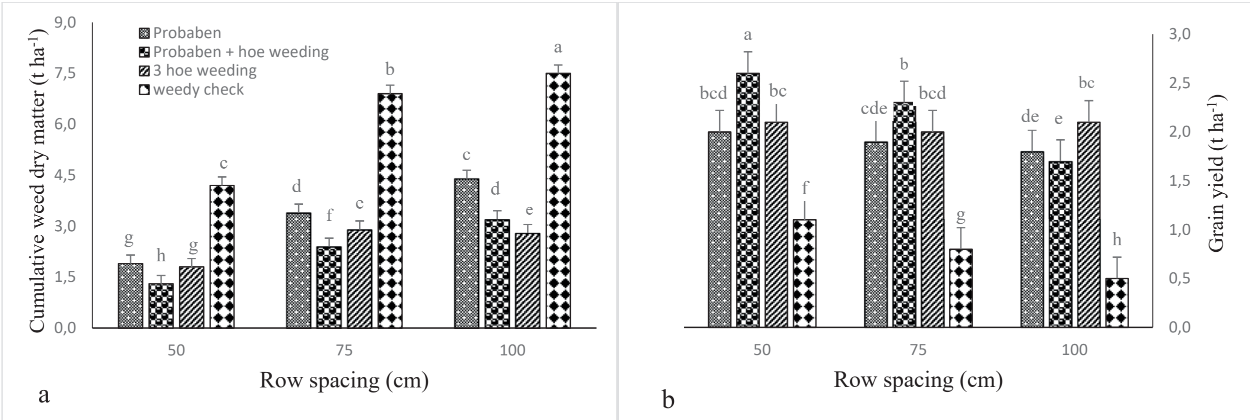

Figure 2. Interactions effects of row spacing and weed management methods on cumulative weed dry matter (a) and soybean grain yield (b). Means represent 2-year average. The columns denote means ± standard error; means labelled with the same case letter do not differ significantly from one another ($P = 0.05$).

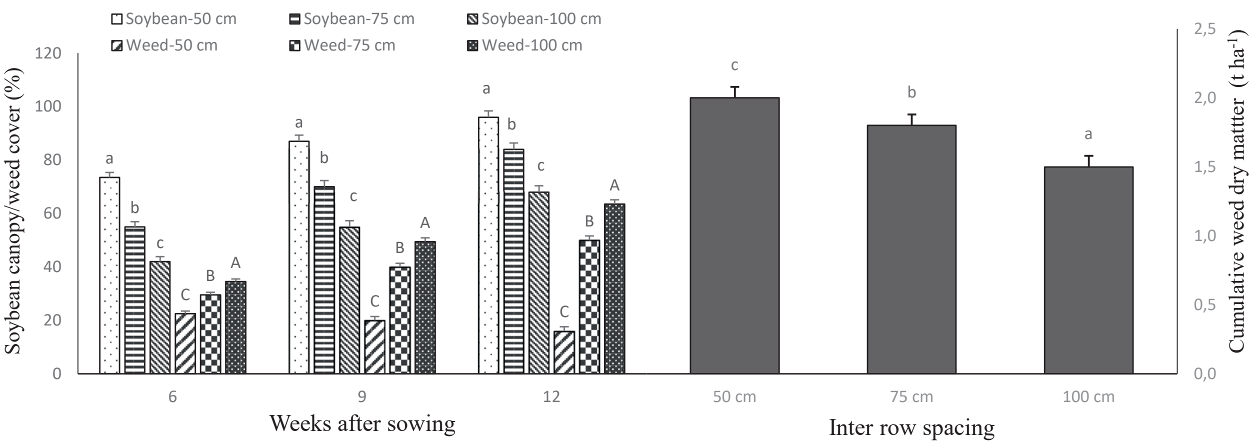

Figure 3. Mean soybean canopy and weed cover score (data averaged for 2-years) at 6, 9 and 12 Weeks after sowing at three row spacings (50, 75 and 100 cm). Cumulative weed dry matter at each row spacing are presented as histogram. The column denote means ± standard error; means labelled with the same lower or upper case letter do not differ significantly from one another ($P = 0.05$) within individual WAS or within individual row spacings.

Table 7. Effect of row spacing and weed management methods on leaf area of soybean in 2016 and 2017

	Leaf area (cm²)					
	12WAS		9WAS		12WAS	
	2016	2017	2016	2017	2016	2017
Row spacing (RS) (cm)						
50	149.6a	139.9a	217.8a	219.1a	225.8a	224.0a
75	132.1b	125.7b	178.2b	176.4b	200.6b	193.0b
100	118.1c	118.0c	165.9c	162.9c	206.3b	206.1b
LSD (5%)	10.9	8.8	10.8	10.5	12.9	16.3
Weed management methods (WM)						
Probaben	162.1a	150.7a	208.4b	206.9b	220.1b	213.0b
Probaben + shw at 6 WAS	160.3a	148.8a	225.1a	219.8a	248.6a	260.2a
3 Hoe weedings	115.6b	115.4b	197.1c	204.6c	255.3a	243.4a
Weedy check	95.0c	96.6c	118.4d	113.3d	119.6b	115.4b
LSD (5%)	12.6	10.2	12.5	12.2	14.8	18.8
RS × WM ($P \leq 0.05$)	21.9 ns	17.7 ns	21.6 ns	21.1 ns	25.8	32.5

WAS – weeks after sowing, shw – supplementary hoe weeding, LSD - Least significant difference, ns – not significant at $P < 0.05$
Means labelled with the same letter do not differ significantly from one another ($P = 0.05$)

at 50 and 75 cm row spacing was recorded in plots treated with probaben at 2.0 kg a.i. ha^{-1} fb shw at 6 WAS. Conversely, for soybean planted at 100 cm row spacing, highest number of leaves and leaf area was obtained with three hoe weedings in both years (Figure 1c).

Effect of row spacing and weed management methods on soybean yield and yield attributes

Soybean grain yield and yield attributes were significantly affected by row spacing and weed management methods in both years (Table 9). There was a significant increase in number of pods, pod weight, grain yield and harvest index with reduction in row spacing from 100 to 75 and 50 cm in both years (Table 9). Soybean grain yield in 50 cm row spaced plots was 12 and 36% (data averaged for both years) higher than yields in 75 and 100 cm row spaced plots, respectively. Similarly, the use of 75 cm row spacing resulted in 21% increase in soybean grain yield than 100 cm row spacing in both years (Table 9).

All the weed management methods resulted in significantly higher soybean yield and yield attributes compared to the weedy check in both years (Table 9). Pre-emergence application of probaben at 2.0 kg a.i. ha^{-1} fb shw at 6 WAS resulted in significantly higher number of pods, pod weight, grain yield and harvest index than three hoe weedings or probaben applied alone in both years (Table 9). Three hoe weedings resulted in significant increase in number of pods, pod weights and grain yield than probaben applied alone in both years. However, three hoe weedings and probaben applied alone resulted in comparable harvest index in both years (Table 9)

Row spacing and weed management methods interacted significantly on soybean grain yield in both years (Figure 2). Highest grain yield (2.6 t ha^{-1} average of both years) was obtained in crops grown in 50 cm rows and treated with probaben at 2.0 kg a.i. ha^{-1} fb shw at 6 WAS, while lowest grain yield (0.3 t ha^{-1} average of both years) was obtained in crops grown in 100 cm rows and kept weedy throughout the crop life cycle (Figure 2). In both years, highest grain yield for crops grow in 50 and 75 cm rows was obtained with pre-emergence application of probaben at 2.0 kg a.i./ha fb shw at 6 WAS. Conversely, for crops grown at 100 cm row spacing, highest grain yield was obtained with three hoe weedings in both years (Figure 2). Uncontrolled weed growth throughout the crop life cycle resulted in 57, 65 and 82% (data averaged for both years) reduction in potential soybean grain yield when the crops were planted at 50, 75 and 100 cm row spacings, respectively in both years. Our result showed that the use of 50 cm row spacing increased soybean grain yield by 37 and 267% under full season weed competition (weedy check) and by 13 and 53% with maximum weed control obtained with probaben applied at 2.0 kg a.i. ha^{-1} fb shw at 6 WAS compared to 75 and 100 cm row spacings, respectively.

DISCUSSION

Our study showed that weed cover, weed density and weed dry matter increased significantly with reduction in soybean row spacing from 100 to 75 and 50 cm. This was probably due to increased crop competitiveness and rapid canopy closure which may have limited light penetration to the weeds emerging below soybean canopy at narrow compared to wide row spacing (Dalley et al., 2004). That idea was supported by our observations that soybean planted in narrow (50 cm) row spacing achieved 71–76% canopy closure compared to about 52–58 and 38–46% in intermediate (75 cm) and wide (100 cm) row spacing, respectively at 6 WAS. The crop utilized these changes in canopy formation for improved weed control, with soybean canopy cover showing contrasting responses to weed cover (Figure 3). This may be due to the smothering effect of soybean canopy on weeds during the growing season. It has been reported that canopy cover reduced weed seeds germination by impeding the light to reach the seeds at the soil surface and also facilitate suppression of emerging weed seedlings (Steckel and Sprague, 2004). The lower weed cover due to rapid canopy formation at 50 compared to 75 and 100 cm row spacings carried through to 12 WAS, resulting in lower weed dry matter production (Figure 3) which had substantial influence on yield of soybean. This pattern of rapid canopy cover, and reduced weed growth with reduction in row spacing is consistent with the results of Bhagirath et al. (2016) and Adigun et al. (2017).

The significant increase in plant height, number of leaves, leaf area, crop dry matter, number of root nodules, number of pods and seed, pod weight as well as grain yield of soybean with reduction in row spacing from 100 to 75 and 50 cm in both years was possibly due to reduced weed competition for growth resources with reduction in row spacing. Acciaresi and Zuluaga (2006) have shown that there is a better use of resources (moisture, light and nutrient) at narrow compared to wide row spacing as a result of reduction in weed competition. In addition, higher crop biomass and rapid canopy development at narrow row spacing allows more light to be intercepted per unit leaf area index at the critical periods, thereby increasing photosynthetic rates of the leaves, and hence dry matter and assimilate production to support pod and seed development (Zhou et al., 2011). This is supported by our observation that soybean planted at 50 cm row spacing accumulated higher dry matter at the detriment of infesting weed species which had lower dry matter compared to weeds growing in 75 and 100 cm row spaced plots at 6, 9 and 12 WAS. As illustrated in Figure 5, when the weed dry matter was low, the rapid accumulation of dry matter

Table 8. Effect of row spacing and weed management methods on dry matter and number of root nodules of soybean in 2016 and 2017

	Dry matter m $^{-2}$						Number of root nodules m $^{-2}$			
	6WAS		9WAS		12WAS		9WAS		12WAS	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Row spacing (RS) (cm)										
50	380.3a	373.0a	646.0a	643.8a	692.0a	689.8a	16.5a	16.3a	24.7a	24.2a
75	204.3b	200.7b	463.3b	412.4b	480.2b	417.9b	12.7b	13.0b	19.8b	19.0b
100	142.5c	142.1c	308.0c	326.2c	305.7c	315.2c	9.3c	8.3c	11.7c	10.3c
LSD (5%)	65.9	66.2	21.6	26.6	24.1	25.0	1.9	2.2	1.2	1.4
Weed management methods (WM)										
Probaben	243.5b	239.6b	423.0c	578.7c	456.8c	634.7c	14.3b	14.2b	17.9b	16.8c
Probaben + shw at 6 WAS	308.2a	305.0a	640.6a	874.8a	657.8a	930.3a	17.0a	16.9a	24.1a	23.0a
3 Hoe weedings	268.4b	263.6b	542.7b	633.7b	567.1b	698.2b	14.0b	12.8b	23.6a	22.6a
Weedy check	149.1c	146.2c	283.4d	488.0d	288.9d	496.0d	6.2c	6.1c	9.2c	9.0b
LSD (5%)	74.2	76.4	24.9	68.8	27.8	29.2	2.2	2.6	1.3	1.6
RS × WM ($P \leq 0.05$)	129.3 ns	132.3 ns	43.2 ns	51.2 ns	48.3 ns	52.1 ns	3.9 ns	4.5 ns	2.4 ns	2.8 ns

WAS – weeks after sowing, shw – supplementary hoe weeding, LSD - Least significant difference, ns – not significant at $P < 0.05$
Means labelled with the same letter do not differ significantly from one another ($P = 0.05$)

Table 9. Effect of row spacing and weed management methods on soybean yield and yield attributes in 2016 and 2017

	Number of pods m $^{-2}$		Pod weight m $^{-2}$		Grain yield kg ha $^{-1}$		Harvest index (%)	
	2016	2017	2016	2017	2016	2017	2016	2017
Row spacing (RS) (cm)								
50	2406.3a	2390.1a	508.1a	500.7a	2003a	1985a	39.8a	39.5a
75	1672.2b	1655.3b	452.3b	452.3b	1807b	1748b	37.4b	36.4b
100	852.1c	768.4c	238.2c	229.6c	1517c	1458c	34.1c	32.9c
LSD (5%)	250.1	240.3	82.1	80.8	161.6	159.6	1.3	1.0
Weed management methods (WM)								
Probaben	1511.2c	1464.2c	237.1c	361.4b	1931c	1886c	39.4b	38.6b
Probaben + shw at 6 WAS	2447.3a	2368.3a	618.4a	608.0a	2302a	2256a	44.5a	43.8a
3 Hoe weedings	2015.5b	2015.3b	414.3b	411.7b	2086b	2041b	39.8b	39.1b
Weedy check	600.0d	569.3d	198.5d	193.3c	784d	738d	22.3c	21.1c
LSD (5%)	288.8	277.5	94.8	93.3	186.6	184.3	1.6	1.8
RS × WM ($P \leq 0.05$)	500.1 ns	480.6 ns	164.1 ns	161.5 ns	323.2	319.3	2.9 ns	3.1 ns

WAS – weeks after sowing, shw – supplementary hoe weeding, LSD - Least significant difference, ns – not significant at $P < 0.05$
Means labelled with the same letter do not differ significantly from one another ($P = 0.05$)

by soybean early in the season carried through to maturity, which may have resulted in higher grain yield recorded at narrow row spacing. Yield formation in soybean has been attributed as a function of dry matter accumulation and its subsequent partitioning to sink (Rahman et al., 2013). The observed increase in growth and yield of soybean in narrow rows in this study is in agreement with earlier studies in soybean (Bowers et al. 2002; Acikgoz et al., 2009) as well as other legumes, including cowpea (Osipitan et al., 2013; Adigun et al., 2014) and groundnut (Adigun et al., 2017).

The higher reduction of weed cover, weed density and weed dry matter by probaben at 6 WAS compared to hoe weeding may be attributed to their mode of action in inhibiting protein synthesis and other processes vital for weed-plant development (Badmus et al., 2006). As this herbicide was taken up mainly through root and coleoptile, the weeds were killed before, at or shortly after emergence. Its excellent herbicidal activity efficiently controlled the first flush of the weeds and provided adequate conditions for growth of the crop, which could explain its initial advantage over hoe-weeding. Since this herbicide was active at the time of germination of weeds, however, it did not control the later flushes of weeds. This was evidenced from the higher weed density and dry matter at 12 WAS and cumulative weed dry matter recorded in plots treated with probaben alone, compared with plots treated with probaben and followed by supplementary hoe weeding at 6 WAS. These results suggest that pre-emergence herbicides application require supplementary hoe weeding for season-long weed control due to their

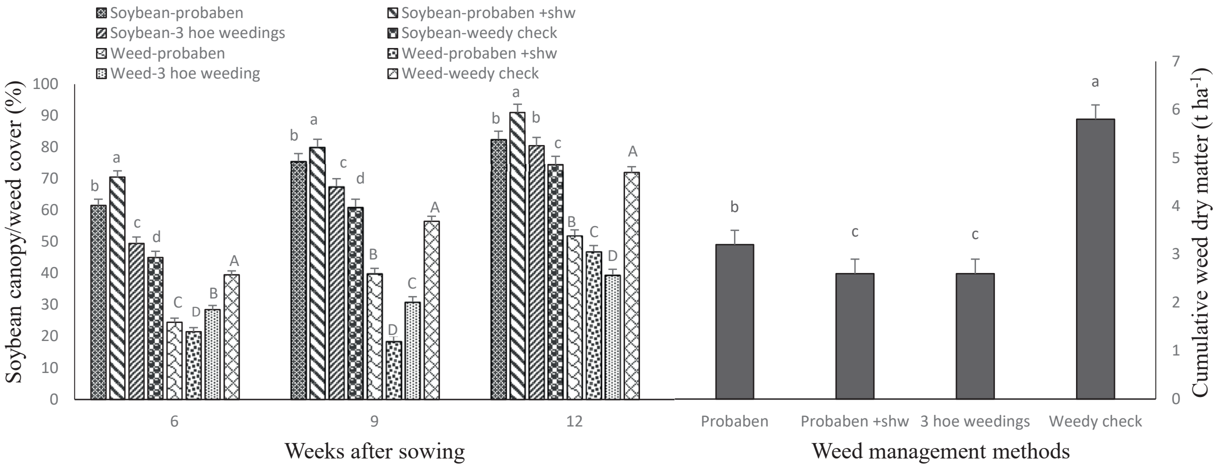

Figure 4. Mean soybean canopy and weed cover score (data averaged for 2-years) at 6, 9 and 12 Weeks after sowing in three weed management methods (Pre-emergence application of propaben, propaben + hoe weeding at 6 WAS, 3 hoe weedings at 3, 6 and 9 WAS) and weedy check. Cumulative weed dry matter in each weed management method are presented as histograms.
The column denote means ± standard error; means labelled with the same lower or upper case letter do not differ significantly from one another (P = 0.05) within individual WAS or within individual weed management methods.

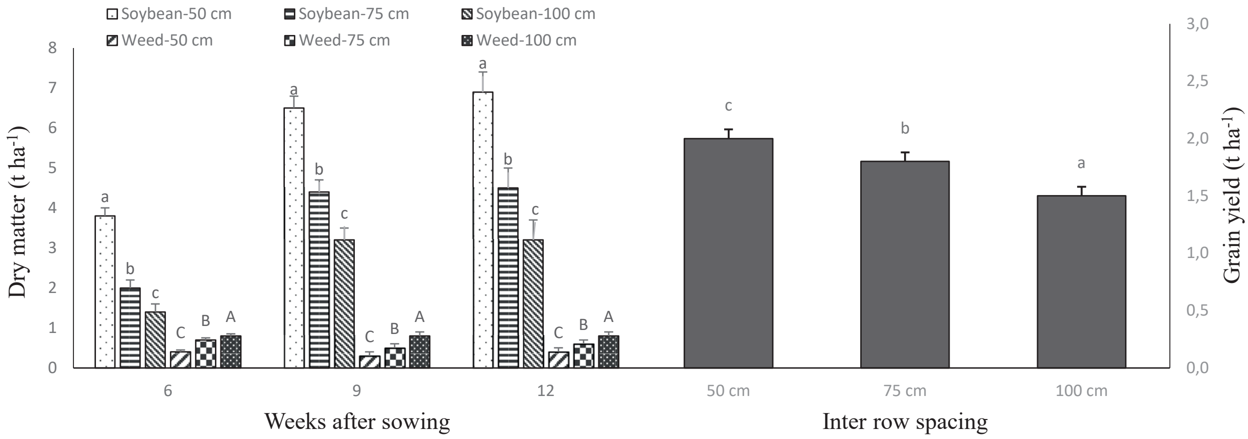

Figure 5. Mean soybean and weed dry matter (data averaged for 2-years) at 6, 9 and 12 Weeks after sowing at three row spacings (50, 75 and 100 cm). Grain yield at each row spacing are presented as histogram. The column denote means ± standard error; means labelled with the same lower or upper case letter do not differ significantly from one another (P = 0.05) within individual WAS or within individual row spacings.

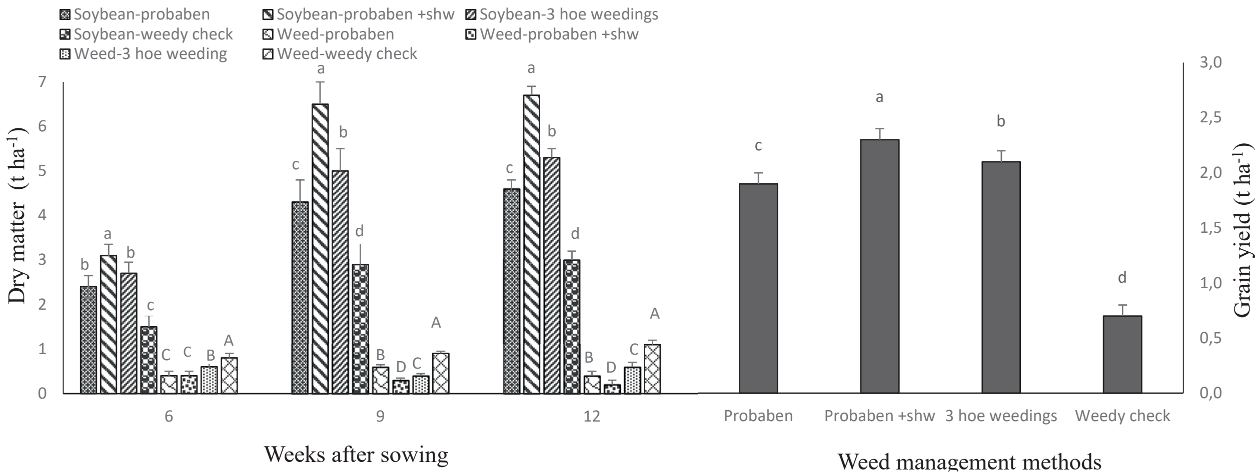

Figure 6. Mean soybean and weed dry matter (data averaged for 2-years) at 6, 9 and 12 Weeks after sowing in three weed management methods (Pre-emergence application of propaben, propaben + hoe weeding at 6 WAS, 3 hoe weedings at 3, 6 and 9 WAS) and weedy check. Grain yield in eachweed management method are presented as histogramsThe column denote means ± standard error; means labelled with the same lower or upper case letter do not differ significantly from one another (P = 0.05) within individual WAS or within weed individual management methods.

short persistence. Our results confirm the earlier report of Badmus et al. (2006) that most pre-emergence herbicides can give initial control of weed seedlings but loose efficacy thereafter thus allowing late emerging weeds to re-infest plots.

Soybean capitalized on the changes in weed competition across the weed control treatments, with soybean plant height, number of leaves and leaf area showing contrasting responses to weed density and weed dry matter. The extent to which these growth parameters increased as the season progressed, depended on how efficiently the weeds were controlled. These patterns further reflected in soybean dry matter accumulation with soybean dry matter showing contrasting responses to weed dry matter beginning at 6 WAS to maturity (Figure 6). When weed dry matter was less with application of probaben followed by supplementary hoe weeding, the higher soybean dry matter carried through till maturity, resulting in higher pods and pod weight and ultimately grain yield of soybean. Reduction in soybean dry matter accumulation with increasing weed dry matter across the treatments may be due to limited supply and use of growth resources that led to reduction in assimilatory surface area (Khaliq et al., 2012) and hence reduced assimilation during early growth period and its subsequent partitioning at maturity (Matloob et al., 2015). These responses are consistent with those reported by Adigun et al. (2017) in the presence of similar weed species in groundnut.

The interactions effects of row spacing and weed management methods on weed dry matter, number of leaves, leaf area and grain yield of soybean shows that there is potential to reduce the number of hoe weeding through pre-emergence application of probaben at 50 or 75 cm compared to 100 cm row spacing, and still attain lower weed dry matter, and ultimately higher soybean grain yield. The rapid canopy closure additionally contributed to the decline in weed dry matter and increased yield obtained with pre-emergence application of probaben followed by hoe weeding at 50 and 75 cm compared to 100 cm row spacing. Soybeans planted at 50 and 75 cm row spacings provided more ground cover and shading of weeds, which gave them a competitive advantage over weeds enabling pre-emergence application of probaben followed by hoe weeding at 6 WAS to be sufficient for the whole season. As a result of rapid canopy cover, weed dry matter between 9 and 12 WAS was 27–68% lower at 50 and 75 cm compared to 100 cm row spacing in both years (Table 3). This result is in agreement with the report of Imoloame (2014) that if weeds were controlled within the first five weeks after sowing, the canopy of narrow row soybean can suppress late emerging weeds. Based on earlier research, lower grain yield of soybean recorded with three hoe weedings compared to pre-emergence application of probaben followed by hoe weeding at 50 and 75 cm row spacing is possibly a result of mechanical damage effect of frequent hoe weeding on root, leaves and reproductive part such as flowers and nodes of closely spaced crops (Adigun et al., 2014). In contrast, the yield increase with three hoe weedings compared to other weed control treatments at wide row spacing may be attributed to the fact that three hoe weedings provided better weed control, higher leaf and leaf area formation than other treatments at wide (100 cm) spacing. Late canopy closure at wide (100 cm) row spacing was accompanied by higher weed pressure and late season weed competition (Figure 3). Consequently, pre-emergence application of probaben alone or followed by hoe weeding at 6 WAS was not sufficient to give full-season weed control and optimum yield for soybean planted at wide (100 cm) row spacing. These results have corroborated the reports of Norsworthy et al. (2007) that wide row spacing requires multiple hoe weeding to achieve a reasonable level of weed control and optimum yield. The result of this study indicate that pre-emergence application of probaben followed by hoe weeding at 6 WAS was more effective under narrow and intermediate than wide row systems because weed were less vigorous as a result of improved crop competitiveness and rapid canopy closure. Similarly, probaben applied alone was more effective the narrower the row spacing, however, this was not sufficient to provide season-long weed control without supplementary hoe weeding.

CONCLUSION

The results of this study demonstrate the benefits of narrow (50 cm) over intermediate (75 cm) and wide (100 cm) row spacings for early vigour, weed competitiveness and consequently higher soybean yield. Likewise, early weed control with pre-emergence application of probaben at 2.0 kg a.i./ha followed by supplementary hoe weeding at 6 WAS suppressed weeds and increased soybean growth, which carried through to final dry matter and yield. Farmers can therefore reduce labour cost for hoe weeding with the use of narrow row spacing and pre-emergence application of herbicide such as probaben to control the first flush of weed in soybean production. This can be supplemented by hoe weeding at 6 weeks after sowing to remove the weeds that escaped herbicide application. Weeds coming in the second flush will be rendered uncompetitive or smothered under soybean canopy at narrow rows. This can be of advantage to smallholder farmers in SSA given the general high cost and shortage of labour for multiple hoe weeding.

REFERENCES

Abate T., Alene A., Bergvinson N. (2012): Tropical Grain Legumes in Africa and South Asia: Knowledge and Opportunities. Nairobi, Kenya: ICRISAT.

Acciaresi H. A., Zuluaga M. S. (2006): Effect of plant row spacing and herbicide use on weed aboveground biomass and corn grain yield. Planta Daninha 24: 287–293.

Acikgoz E., Sincik M., Karasu A., Tongel O., Wietgrefe G., Bilgili U., Oz M., Albayrak S., Turan Z. M., Goksoy A. T. (2009): Forage soybean production for seed in Mediterranean environments. Field Crops Research 110: 213–218.

Adigun J. A., Lagoke S. T. O. (2003): Weed control in transplanted rain and irrigatedtomatoes in the Nigerian savanna. Nigerian Journal of Weed Science 16: 23–29.

Adigun J. A. (2005): Critical period of weed interference in rainfed and irrigated Tomatoes in the Nigerian savanna. Agricultura Tropica et Subtropica 38: 73–79.

Adigun J. A., Osipitan A. O., Lagoke S. T., Adeyemi R. O., Afolami S. O. (2014): Growth andyield performance of cowpea (*Vigna unguiculata* (L.) Walp) as influenced by row-spacing and period of weed interference in South-West Nigeria. Journal of Agricultural Science 6: 188–198.

Adigun J. A., Daramola O. S., Adeyemi O. R., Olorunmaiye P. M., Osipitan, O. A., Idiodemise O. (2017): Effects of Row-Spacing and Period of Weed Interference on Growthand Yield of Cowpea (*Vigna unguiculata* (L.) Walp). Nigerian Journal of Ecology 16: 88–100.

Badmus A. A., Lagoke S. T. O., Adigun J. A., Okeleye K. A. (2006): Effects of intercropping groundnut and weed control methods on maize production in South Western Nigeria. ASSET series 6: 289–296.

Beadle C. L. (1987): Plant Growth Analysis. In: Techniques in Bio-productivity and Photosynthesis; 2nd ed. J. Coombs, D.O Hall, S.P. Long and J. M. O. Sacrlock (Eds.) Pregamon Press. Oxford New York. U.S.A. pp. 21–23.

Bhagirath S., Chauhan, J. H., Opeña L. (2013): Effect of Plant Spacing on Growth and Grain Yield of Soybean. American Journal of Plant Sciences 4: 2011–2014.

Bhagirath S. C., Singarayer K. F., Connor J. F., Cheretto R. G. (2016): Implications of narrow crop row spacing in managing weeds in mungbean (*Vigna radiata*). Crop Protection 30: 1–4.

Bowers G. R., Rabb J. L., Ashlock L. O., Santini J. B. (2002): Row Spacing in the early soybean production system. Agronomy Journal 92: 524–531.

Buhler D. D., Gunsolus J. L., Raiston D. F. (1999): Integrated weed management techniquesto reduce herbicide inputs in soybeans. Agronomy Journal 84: 973–978.

Chauhan B. S., Migo T., Westerman P. R., Johnson D. E. (2010): Post-dispersal predation of weed seeds in rice fields. Weed Research 50: 553–560.

Chauhan B. S., Opeña J. (2013): Implications of plant geometry and weed control options in designing a low-seeding seed-drill for dry seeded rice systems. Field Crops Research 144: 225– 231.

Chikoye D., Ellis-Jones J., Riches C., Kanyomeka L. (2007): Weed management in Africa: experiences, challenges and opportunities. XVI International Plant Protection Congress. Pp. 652–653.

Cox W. J., Cherney J. H. (2011): Growth and Yield Response of Soybean to Row Spacing and Seeding Rate. Agronomy Journal 103: 123–128.

Dalley C. B., Kells J. J., Renner K. A. (2004): Effect of glyphosate application timingand row spacing on weed growth in corn (*Zea mays*) and soybean (*Glycine max*). Weed Technology 18: 177–182.

FAO (2014): Sustainable crop production intensification. Rome, http://www.fao.org/agriculture/crops/thematic-sitemap/theme/spi/scpi-home/framework/en/.

Gesimba R. M., Langart M. C. (2005): A review on weeds and weed control in oil crops withspecial reference to soybeans (*Glycine max* L.) in Kenya. Agriculura Tropica et Subtropica 38: 56–62.

Geier P. W., Stahlman P. W., Frihauf J. C. (2006): KIH-485 and S-metolachlor efficacycomparisons in conventional and no-tillage corn. Weed Technology 20: 622–626.

Gricher W. J., Bessler B. A., Brever K. O. (2004): Effect of row spacing and herbicides doseon weed control and grain sorghum yield. Crop Protection 23: 263–267.

Imoloame E. O. (2014): The effects of different weed control methods on weed infestation, growth and yield of soybeans (*Glycine max* (L.) Merrill) in the Southern Guinea savanna of Nigeria. Agrosearch 14: 129–143.

Joubert J. C. N., Jooste A.A. (2013): Comparative analysis of different regions of South Africa Soybean industry. Proceedings of the World Soybean Research Conference IX, February 18–22, 2013, Urban, South Africa.

Kercher S. M, Frieswyk C. B, Zedler J. B. (2003): Effects of sampling teams and estimation methods on the assessment of plant cover. Journal of Vegetable Science 14: 899–906.

Khaliq A. A., Matloob S., Mahmood R. N., Abbas M. B., Khan K. (2012): Seeding density and herbicide tank mixture furnishes better weed control and improve the growth, yield and quality of direct seeded fine rice. International Journal of Agricultural Biology 14: 499–508.

Khojely D. M., Ibrahim S. E., Sepey E., Han T. (2018): History, current status, and prospect of soybean production and research in sub-Saharan Africa. The Crop Journal 6, 226–235.

Kolapo A.L. (2011): Africa's potential Cinderella food crop, in: N.G. Tzi-Bun (Ed.), Soybean: Biochemistry,

Chemistry and Physiology, In Tech, Rijeka, Croatia 2011: 137–150.

Matloob A., Khaliq A., Tanveer A., Hussain S., Aslam F., Chauhan B. S. (2015): Weed dynamics as influenced by tillage system, sowing time and weed competition duration in dry seeded rice. Crop Protection 71: 25–38.

Nikoa R, M., Owen D. K., Swanton C. J. (2015): Weed Abundance, Distribution, Diversity, and Community Analyses. Weed Science 63: 64–90.

Norsworthy J. K. (2004): Broad leaved weed control in wide-row soybean (*Glycine max*) using conventional and glyphosphate herbicide programmes. Crop Protection 23: 1229–1235.

Oerke E. C., Dehne H. W. (2004): Safeguarding production-losses in major crops and the role of crop protection. Crop Production 23: 275 – 285.

Osipitan O. A., Adigun J. A., Lagoke S. T. O., Afolami S. O. (2013): Effect of inter-row spacing and weed control methods on growth and yield of cowpea (*Vigna unguiculata* L.Walp) in South Western Nigeria. Nigeria Journal of Plant Protection 27: 97–111.

Powles S. B., Yu Q. (2010): Evolution in action: Plant resistance to herbicides. Annual Review of Plant Biology 61: 317–347.

Rahman M. M., Rahman M. M., Hossain M. M. (2013): Effect of Row Spacing and Cultivar on the Growth and Seed Yield of Soybean (*Glycine max* L.) in Kharif-II Season. The Agriculturists 11: 33–38.

Rusike J., Van den Brand G., Boahen S., Dashiell K., Kantengwa S., Ongoma J., Mongane, D. M., Kasongo G. Jamangani Z. B., Aidoo R., Abaidoo R. (2013): Value Analyses of Grain Legumes in N2 Africa: Kenya, Rwanda, Eastern DRC, Ghana, Nigeria, Mozambique, Malawi and Zimbabwe, http://www.n2africa.org/sites/n2africa.org/files/images/N2Africa_Value%20chain%20analyses%20of20grain%20legumes%20in%20N2Africa.pdf201

Sanginga N., Dashiell K., Diels J. (2003): Sustainable resource management coupled to resilient germplasm to provide new intensive cereal–grain legume–livestock systems in the dry Savanna. Agriculture, Ecosystems and Environment 100: 305–314.

Sodangi I. A., Gworgwor N. A., Joshua, S. D. (2006): Effects of weed interference and inter-row spacing on productivity of soyabean (*Glycine* Max (L) Merril) in Maiduguri, Nigeria. Nigerian Journal of Weed Science 19: 33–40.

Steckel L. E., Sprague C. L. (2004): Late season common water hemp (*Amaranthus rudis*) interference in narrow- and wide-row soybean. Weed Technology 18: 947–952.

Tefera H. (2011): Breeding for promiscuous soybean at IITA, in: A. Sudaric (Ed.), Soybean-Molecular Aspect of Breeding, InTech, Rijeka, Croatia, 2011.

Tunku P., Lagoke S. T. O., Ishaya D. B. (2007): Evaluation of herbicides for weed control in irrigated garlic (*Allium sativum* L.) at Samaru, Nigeria. Crop Protection 26: 642–646.

Wiersma J. V. Bailey T. B. (1975): Estimation of leaflet, trifoliate and total leaf area of soybeans. Agronomy Journal 67: 26–30.

Zhou X.B., Chen Y.H., Ouyang Z. (2011): Row spacing effect on leaf area development, light interception, crop growth and grain yield of summer soybean crops in Northern China. African Journal of Agricultural Research 6: 1430–1437.

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