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Influence of Herbicides on Yield, Weight and Size of Soybean Seed

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Abstract
Soybean, (Glycine max) is an annual crop belonging to the family Fabaceae, which is versatile and useful in the economy as human diet, animal feed and for industrial purposes. However, due to its higher price at the time of scarcity, some farmers want reap out that opportunity as such, they hasten the maturity and desiccation of soybean crop by applying herbicides without giving attention to the effects on seed yield and quality. The objective of this study was to investigate the soybean seed yield, seed weight and size quality after herbicides application as desiccant. For this, three cultivars of soybean seed were planted and applied with three types of herbicides Glyphosate, Paraquat, and 2, -4D. The herbicides were sprayed at three stages/time of soybean seed development R6, R7 and R8. The experiment was laid as split-split plot arrangement in RCBD, replicated three times at Busia ATC, Mabanga ATC and University of Eldoret (UoE) in 2017 raining season. Herbicides application reduced all the parameters measured except for the seed size at one location. Similarly, time of application also significantly reduced all the parameters measured except for the seed size at one location. It is recommended that; extra early varieties should be planted so as to avoid the effect of herbicides on the parameters measured.

Keywords: Herbicide, Seed size, Seed weight. Stages of application, Yield

INTRODUCTION
High quality seed is important to ensure maximum seed germination and seedling vigor, which in turn is instrumental in achieving maximum yield (Hussaini, 2014).Soybean seed yield and quality can adversely be affected by several factors both in tropics and subtropical regions among which include the time of sowing and harvesting stages. Kumar *et al.* (2002) reported that seed yield and quality largely depends on the stage of maturity of crops. Therefore, harvesting of seeds at the optimum stage of maturity is important as harvesting either at early or late stage results in lower yields with poor quality seeds.
There are eight reproductive growth stages of soybean, defined as R1 to R8 (Wright and Andrew 2013). The first stage is bloom, which is described as R1 and R2 stage. The second stage is Pod development which is R3 and R4. The R3 was defined as beginning of pod formation. The third category is Seed development stage, R5 and R6. The R5 is beginning of seed. The fourth and last category is described as Maturity stage, R7 and R8. The R7 is Beginning of maturity: One pod on the main stem has reached its mature color (tan, brown,

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or black). The R8 is defined as Full maturity. Ninety-five percent of the pods have reached their mature color.

Herbicides are metabolic inhibitors and their mode of action can be classified into different groups; Photosynthetic inhibitor, Cell growth disrupters (mitotic inhibitors), Growth regulators, Lipid biosynthesis inhibitor, Carotenoid biosynthesis inhibitor and Branch chain amino acid inhibitors(Hess,1999).Herbicide may be classified according to selectivity; as grass control, broad leaf control, pre-emergence or post emergence and persistence (DPIRD,2017).Also, their 'modes of action' either ultimately stop seeds from germinating or establishing as seedlings; prevent plants from making essential carbohydrates, proteins or lipids (oils and fats); or desiccate leaves and stems, (Center, 2018). Diquat is a quick acting contact herbicide that is traditionally used as a harvest aid for lentil. It rapidly and quickly dries plant tissues within few days of application and has no or low translocation in plants (Cobb, 2010; Zhang *et al*., 2016).It can be safely used on pea grown for seed production (Ali, 2010).Glyphosate also is a non-selective herbicide that is readily translocated throughout the plant and accumulates in areas of high meristematic activity.

The price of soybean is higher when it is scarce in the market which is the normal trend. As such, some farmers hasten the maturity and desiccation of soybean crop by applying herbicides without giving attention to the seed yield and quality. Regarding the indication of chemical desiccation, there are conflicting results related to the effect of desiccation on seeds yield of soybean. The yield of soybean can be reduced by the use of desiccants when the application occurs before the physiological maturity (Lamego *et al*., 2013), in indeterminate growth habits of cultivars, the pods are still being formed after the physiological maturity and it is recommended that the desiccation takes place after stage R8 (Zagonel, 2005). It is in this view therefore this study was carried out to determine the yield and quality in terms of size and weight of soybean seed harvested after using herbicides as desiccant.

MATERIALS AND METHODS

Three varieties of soybean seed SB 19, SB 25 and SB 3 obtained from CIAT–TSBR Maseno were planted at three different locations in 2017 raining season. The locations were Busia ATC: tropical climate, temperature 22^{o}C, annual rainfall 1691mm, warmest March, August, coldest. The soil type is loamy, strongly acidic (pH 4.97)., Mabanga ATC: tropical climate, temperature 21.5^{o}C, annual rainfall 1618mm, warmest March and coldest July. The soil type is sandy loam, strongly acidic (pH 5.22) and University of Eldoret: climate is warm and temperate, Temperature 16.8^{o}C, and annual rainfall 1055mm. The soil type is sandy - clay loam, strongly acidic (pH 5.22).

The experiment was laid as split – split plot arrangement in RCBD design and replicated three times in each location. Cultivars were the main plot; herbicides were the sub plot and application stages were the sub – sub plot. The herbicides used are Glyphosate (GLY), Paraquat (PRQ), 2,4-D and the control (C) in which no herbicide was applied. The herbicides were sprayed at three stages of soybean seed development R6, R7, and R8 as described by Wright & Andrew (2013).

The two middle rows as net plot were harvested, threshed and weighted, the values were converted to kg/ha^{-1}. One thousand seeds were counted using an automatic seed counter and the counted seeds were measured using a weighing balance to obtain the weight of each sample. Seed Size (surface area)was determined by measuring the length and multiplied by the width and expressed as mm^{2}.

RESULTS

There were significant differences (P ≤ 0.001) on seed yield among the cultivars at UoE. The cultivar SB19 was significantly different from SB25 and SB3 as it had higher yield of 1087 kg ha-1, compared to 928 kg ha-1 and 492 kg ha-1for SB3 and SB25 respectively. The cultivar SB25 was also significantly different from SB3 since it had lower yield as indicated in Table 1. Significant difference (P ≤ 0.001) on seed yield due to herbicides application was also observed. Control was significantly different from the herbicides as it had higher yield of 1048 kg ha^{-1}, followed by 2,4-D with 795 kg ha-1, GLY with 787 kg ha-1, and PRQ with yield of 713 kg ha^{-1}as indicated in Table 1 below.

Table 1 Effect of soybean cultivars, herbicides and application stages on seed yield (kg/ha) at UoE

Cultivars	Herbicides	Stages			Cultivar mean	Herbicides			
		R6	R7	R8		C	2,4-D	GLY	PRQ
	C	1011	1240	1462		1238			
	2,4-D	684	882	1005			857		
SB3	GLY	590	912	1042	**928^{b}**			848	
	PRQ	519	772	1011					767
	C	1356	1227	1297		1293			
	2,4-D	719	1187	1385			1097		
SB19	GLY	536	1109	1391	**1087^{a}**			1012	
	PRQ	715	975	1147					946
	C	534	543	757		611			
	2,4-D	430	330	535			431		
SB25	GLY	451	445	603	**492^{c}**			500	
	PRQ	332	455	491					426
Herbicides Means						**1047^{a}**	**795^{b}**	**787^{b}**	**713^{b}**
Stage means		**656^{c}**	**840^{b}**	**1011^{a}**					
CV % 22.6									
S.E. D 154									

Means followed by the same letter(s) are not statistically different at 5 % level of probability. R6, R7 and R8 are the stages of herbicides application. C – control, 2, 4-D – 2,4-Dichlorophenoxyacetic Acid, GLY – Glyphosate, PRQ – Paraquat.

There were also significant differences (P ≤ 0.001) on seed yield due to application stages. The stage R8 was significantly higher as it had 1010 kg ha-1followed by R7 with 840 kg ha-1 and R6 had lower 656 kg ha-1. The R7 and R6 also differed significantly (Table1).

Cultivars and stages of application interaction on yield was significant (P ≤ 0.05). The SB19 was significantly different from SB25 and SB3 with higher seed yield of 1305 kg ha-1 in R8. The SB25 had lower seed yield. The R8 was significantly different from R7 and R6, higher in seed yield in all the cultivars. However, in SB25 the difference between R6 and R7 was not significant (Figure 1).

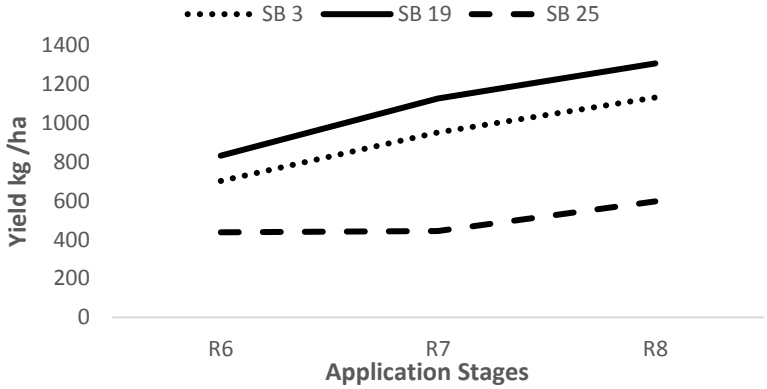

Figure 1: Cultivar and herbicides interaction o seed yield at UoE

There were significant differences on seed yield among the cultivars at Mabanga (P ≤ 0.05). The SB19 was significantly higher with 1136 kg ha-1 compared to SB25 with 794 kg ha-1 which is also higher than SB3 with 507 kg ha-1 (Table 2). Significant differences (P ≤ 0.05) on seed yield among the herbicides were also observed. Control had higher yield with 983 kg ha-1 compared to 2,4-D with 907 kg ha-1, though not significantly different, but was significantly different from GLY and PRQ with 681 kg ha-1 and 679 kg ha-1 respectively.

Table 2 Effect of soybean cultivars, herbicides and application stages on seed yield (kg/ha) at Mabanga

Cultivars	Herbicides	Stages			Cultivar mean	Herbicides			
		R6	R7	R8		C	2,4-D	GLY	PRQ
SB3	C	343	519	1079		647			
	2,4-D	236	601	941			593		
	GLY	377	514	559	**507^{c}**			483	
	PRQ	182	291	444					306
SB19	C	974	1423	1701		1366			
	2,4-D	847	1061	1432			1113		
	GLY	674	984	1169	**1136^{a}**			942	
	PRQ	898	1051	1420					1123
SB25	C	735	843	1228		935			
	2,4-D	680	969	1399			1016		
	GLY	391	564	895	**794^{b}**			617	
	PRQ	422	627	778					609
Herbicides Means						**983^{a}**	**907^{a}**	**681^{b}**	**679^{b}**
Stage means		**563^{c}**	**787^{b}**	**1087^{a}**					
CV % 21.0									
S.E. D 205									

Means followed by the same letter(s) are not statistically different at 5 % level of probability. R6, R7 and R8 are the stages of herbicides application. C – control, 2, 4-D – 2,4-Dichlorophenoxyacetic Acid, GLY – Glyphosate, PRQ – Paraquat.

The GLY and PRQ were not significantly different but 2,4-D was significantly different from GLY and PRQ (Table 2). Highly significant differences (P ≤ 0.001) on seed yield due to application stage were also observed. The R8 stage was higher with 1087 kg ha-1 followed by R7 with 787 kg ha-1 and R6 had lower yield of 563 kg ha-1 (Table 2).

There was no significant difference on seed yield among the cultivars at Busia (Table 3). However, significant differences (P ≤ 0.05) on seed yield due to herbicides application were observed. Control had the higher yield of 1042 kg ha-1 though not significantly different from 2,4-D with 864 kg ha-1 but was significantly different from GLY with 851 kg ha-1 and PRQ with 699 kg ha-1. The GLY and PRQ were not significantly different but 2,4-D was significantly different from PRQ yet not significantly different from GLY (Table 3). Significant difference (P ≤ 0.001) on seed yield due to application stage was recorded. The R8 was significantly higher with 1121 kg ha-1 followed by R7 which has 855 kg ha-1 and R6 with lower seed yield of 616 kg ha-1 (Table 3).

Table 3 Effect of soybean cultivars, herbicide and application stage on seed yield (kg/ha) at Busia

Cultivars	Herbicides	Stages			Cultivar mean	Herbicides			
		R6	R7	R8		C	2,4-D	GLY	PRQ
	C	690	820	1325		945			
	2,4-D	432	719	863			671		
SB3	GLY	581	742	992	**750[a]**			772	
	PRQ	506	633	691					610
	C	863	1057	1483		1134			
	2,4-D	759	1077	1132			989		
SB19	GLY	725	880	1137	**947[a]**			914	
	PRQ	433	759	1062					751
	C	877	928	1333		1046			
	2,4-D	453	1026	1312			930		
SB25	GLY	653	830	1120	**895[a]**			868	
	PRQ	419	793	995					736
Herbicides Means						**1042[a]**	**864[b]**	**851[b]**	**699[c]**
Stage means		**616[c]**	**855[b]**	**1120[a]**					
CV % 17.3									
S.E. D 149									

Means followed by the same letter(s) are not statistically different at 5 % level of probability. R6, R7 and R8 are the stages of herbicides application. C – control, 2, 4-D – 2,4-Dichlorophenoxyacetic Acid, GLY – Glyphosate, PRQ – Paraquat.

Effect of Soybean cultivars, herbicides and application stages on TSW at UoE, Mabanga and Busia

There were significant differences ($P \leq 0.001$) on TSW among the soybean cultivars at UoE. Cultivar SB19 had highest weight of 122 g followed by SB3 with 115 g and SB25 had the lowest weight of 97 g. The two cultivars SB19 and SB3 also differed significantly (Table 4). There were also significant differences on TSW due to herbicides application ($P \leq 0.001$). Control was significantly different from the herbicides with higher weight of 119 g followed by GLY with 112 g though not significantly different from 2,4-D with 110 g and PRQ was lower with TSW of 104 g (Table 4). Thousand seed weight was significantly different among the application stages ($P \leq 0.001$). The stage R8 was significantly different from R6 as it had 119 g followed by R7 with 115 g and R6 had lower weight of 100 g. The R7 was also significantly different from R6 (Table 4).

Table 4 Effect of soybean cultivars, herbicides and application stages on TSW (g) at UoE

Cultivars	Herbicides	Stages			Cultivar mean	Herbicides			
		R6	R7	R8		C	2,4-D	GLY	PRQ
	C	118.3	120.7	125.7		121.6			
	2,4-D	107.2	121.9	121.1			116.7		
SB3	GLY	95.6	118.9	120.4	**114.8^{b}**			111.6	
	PRQ	85.6	120.2	122.0					109.3
	C	127.7	130.9	131.8		130.1			
	2,4-D	110.9	123.0	130.1			121.3		
SB19	GLY	107.9	121.3	129.7	**121.9^{a}**			119.7	
	PRQ	101.4	120.1	128.6					116.7
	C	97.6	106.7	111.1		105.1			
	2,4-D	85.9	95.8	109.0			96.9		
SB25	GLY	90.4	96.3	105.9	**96.6^{c}**			97.5	
	PRQ	66.9	98.1	95.2					86.7
Herbicides Means						**118.9^{a}**	**111.7^{b}**	**109.6^{bc}**	**104.2^{c}**
Stage means		**99.6^{b}**	**114.5^{a}**	**119.2^{a}**					
CV % 9.1									
S.E. D 7.0									

Means followed by the same letter(s) are not statistically different at 5 % level of probability. R6, R7 and R8 are the stages of herbicides application. C – control, 2, 4-D – 2,4-Dichlorophenoxyacetic Acid, GLY – Glyphosate, PRQ – Paraquat

The interaction between herbicides and stages on TSW was significant ($P \leq 0.05$). Control had higher TSW of 123 g in R8, significantly different from paraquat. It was also different from all the herbicides treatments at R7. The R8 was significantly different from R7 and R6, higher in TSW in 2,4-D and glyphosate treatments (Table).

Table 5Herbicides and Stages interaction on TSW (g) at UoE

Stages	Herbicides			
	Control	2,4-D	Glyphosate	Paraquat
R6	114.5^{b}	101.3^{bc}	98.1^{c}	84.6^{d}
R7	119.5^{a}	113.6^{b}	112.2^{b}	112.8^{b}
R8	122.9^{a}	120.1^{a}	118.7^{a}	115.3^{b}
S.E.D. 4.7				

Means followed by the same letter(s) are not statistically different at 5 % level of probability

Significant difference ($P \leq 0.05$) on TSW among the cultivars was observed at Mabanga. The cultivar SB25 had higher weight of 162 g and was significantly different from SB19 with131 g and SB3 which had 123 g. However, the two cultivars SB19 and SB3 were not significantly different from each other (Table 6). There was also significant difference on TSW due to herbicides application ($P \leq 0.001$). Control was significantly different from the herbicides with higher weight of 154 g followed by 2,4-D with 139 g, GLY with 132 g and PRQ which had lower weight of 130 g (Table 6). Significant difference ($P \leq 0.001$) on TSW due application stage was also recorded. The R8 stage was significantly different with higher weight of 159 g compared to R7 with 145 g and R6 with lower weight of 112 g. The R7 also differed significantly from R6 (Table 6).

Table 6 Effect of soybean cultivars, herbicides and application stages on TSW (g) at Mabanga

Cultivars	Herbicides	Stages			Cultivar	Herbicides			
		R6	R7	R8	mean	C	2-4D	GLY	PRQ
	C	130.8	135.9	161.6		142.8			
	2-4D	87.3	134.1	142.8			121.4		
SB3	GLY	84.9	125.7	136.9	**123.4^{b}**			115.8	
	PRQ	86.1	117.5	137.0					113.5
	C	132.6	139.4	144.6		138.9			
	2-4D	122.3	128.5	139.8			130.2		
SB19	GLY	89.2	134.8	144.5	**130.8^{b}**			122.8	
	PRQ	115.3	132.1	146.9					131.4
	C	165.5	181.1	197.1		181.2			
	2-4D	133.3	169.2	191.3			164.6		
SB25	GLY	109.4	175.7	183.4	**161.9^{a}**			156.2	
	PRQ	84.0	170.1	183.3					145.8
Herbicides Means						**154.3^{a}**	**138.7^{b}**	**131.6^{b}**	**130.3^{b}**
Stage means		**111.7^{b}**	**145.3^{b}**	**159.1^{a}**					
CV % 10.4									
S.E. D 14.0									

Means followed by the same letter(s) are not statistically different at 5 % level of probability. R6, R7 and R8 are the stages of herbicides application. C – control, 2, 4-D – 2,4-Dichlorophenoxyacetic Acid, GLY – Glyphosate, PRQ – Paraquat

Cultivars and stages interaction on TSW were significant (P ≤ 0.001). The cultivar SB25 had the higher TSW of 189 g in R8 significantly different from SB 19 and SB3. The cultivars SB3 and SB19 were statistically similar at R7 and R8. However, R6 had the lower weight across all the cultivars (Figure 2).

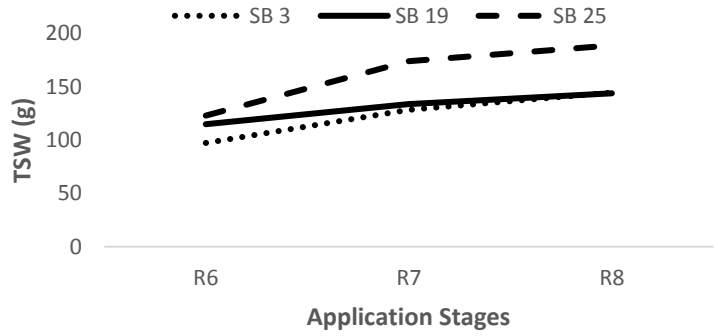

Figure 2: Herbicides and Stages interaction on TSW (g) at Mabanga

The cultivar SB25 was significantly different with the higher weight of 157 g compared to SB19 and SB3 in which, each had 122 g (Table 7). Also, significant difference (P≤ 0.05) on TSW due to herbicides application was observed. The control had higher weight of 142 g, followed by 2,4-D with 137 g though not significantly different, GLY with 130 g which was also not significantly different from PRQ which had the lower weight of 125 g (Table 7). Significant difference (P ≤ 0.05) on TSW due to application stage was also observed. The stage R8 was significantly different with higher weight of 145 g, compared to R7 with 131 g and R6 which had lower weight of 126 g though, the two were not significantly different (Table 7).

Table 7 Effect of soybean cultivars, herbicides and application stages on TSW (g) at Busia

Cultivars	Herbicides	Stages			Cultivar mean	Herbicides			
		R6	R7	R8		C	2,4-D	GLY	PRQ
	C	146.0	124.2	131.0		133.7			
	2,4-D	120.9	115.9	125.5			120.8		
SB3	GLY	126.1	101.9	128.2	**122^{b}**			118.7	
	PRQ	114.3	102.2	128.7					115.1
	C	121.3	128.2	139.9		129.8			
	2,4-D	116.9	124.9	130.0			123.9		
SB19	GLY	103.9	116.9	132.3	**122^{b}**			117.7	
	PRQ	111.7	108.9	125.2					115.3
	C	143.3	170.1	176.7		163.4			
	2,4-D	157.3	159.9	177.7			165.1		
SB25	GLY	126.7	163.4	169.2	**157^{a}**			153.1	
	PRQ	117.6	151.1	169.4					146.0
Herbicides Means						**142^{a}**	**137^{a}**	**130^{a}**	**126^{ab}**
Stage means		**126^{b}**	**131^{b}**	**145^{a}**					
CV % 20.6									

Means followed by the same letter(s) are not statistically different at 5 % level of probability. R6, R7 and R8 are the stages of herbicides application. C – control, 2, 4-D – 2,4-Dichlorophenoxyacetic Acid, GLY – Glyphosate, PRQ – Paraquat

Effect of Soybean cultivars, herbicides and application stages on seed size at UoE, Mabanga and Busia.

The cultivar SB19 with seed size of 41 mm^2 was significantly different from SB25 with 36 mm^2 but did not differ with SB3 which had 40 mm^2. The cultivar SB25 and SB3 were also significantly different (Table 8). There was also significant difference ($P \leq 0.001$) on seed size due to herbicides application. Control was significantly different and bigger with seed size of 47 mm^2 compared to 2,4-D with 37 mm^2, GLY and PRQ with 36 mm^2 each (Table 8). Also, significant differences ($P \leq 0.001$) on seed size due to application stages ware observed. The stage R8 was significantly bigger in seed size as it had 45 mm^2, compared to R7 with 39 mm^2 and R6 which had smaller seed size of 33 mm^2. The R7 was also significantly different from R6 (Table 8).

Table 8. Effect of soybean cultivars, herbicides and application stages on seed size (mm²) at UoE

Cultivars	Herbicides	Stages			Cultivar mean	Herbicides			
		R6	R7	R8		C	2,4-D	GLY	PRQ
SB3	C	47.6	47.9	48.9	**39.5**[a]	48.1			
	2,4-D	29.0	34.6	48.7			37.4		
	GLY	26.8	32.8	47.7				35.8	
	PRQ	30.7	38.5	40.4					36.6
SB19	C	50.4	49.4	53.6	**41.4**[a]	51.1			
	2,4-D	30.3	41.2	45.2			38.9		
	GLY	29.4	36.1	46.6				37.4	
	PRQ	29.3	39.8	45.3					38.1
SB25	C	43.2	42.8	43.0	**35.9**[b]	43.1			
	2,4-D	24.6	35.4	39.2			33.1		
	GLY	25.1	36.0	39.3				33.5	
	PRQ	25.4	32.5	44.2					34.0
Herbicides Means						**47.4**[a]	**36.5**[b]	**35.5**[b]	**36.2**[b]
Stage means		**32.6**[c]	**38.9**[b]	**45.2**[a]					
CV % 11.3									
S.E. D 3.1									

Means followed by the same letter(s) are not statistically different at 5 % level of probability. R6, R7 and R8 are the stages of herbicides application. C – control, 2, 4-D – 2,4-Dichlorophenoxyacetic Acid, GLY – Glyphosate, PRQ – Paraquat.

Cultivar SB25 with seed size of 41 mm² was significantly different from SB3 which had 35 mm² and also had bigger size than SB19 which had 37 mm² though not significantly different (Table 9). There was also significant difference ($P \leq 0.001$) on seed size due to herbicides application. Control had bigger seed size significantly different from the herbicides. Its seed size measured was 41 mm² which was bigger when compared to 2,4-D with 38 mm², GLY with 37 mm² and PRQ with 33 mm². The 2,4-D was not significantly different from GLY but differed significantly with PRQ. Moreover, GLY was significantly different from PRQ as such, PRQ had the smallest seed size (Table 9). Significant difference ($P \leq 0.001$) on seed size due to application stages was also observed. The stage R8 was significantly bigger in seed size as it had 45 mm², compared to R7 with 38 mm² and R6 which had smaller seed size of 31 mm². The R7 also differed significantly with R6 (Table 9).

Table 9. Effect of soybean cultivars, herbicides and application stages on seed size (mm²) at Mabanga

Cultivars	Herbicides	Stages			Cultivar mean	Herbicides			
		R6	R7	R8		C	2,4-D	GLY	PRQ
	C	30.5	32.0	32.7		31.7			
	2,4-D	29.8	38.1	43.1			37.0		
SB3	GLY	32.0	37.5	40.3	**34.6^{b}**			36.6	
	PRQ	25.6	35.0	38.7					33.1
	C	40.4	46.6	49.4		45.5			
	2,4-D	27.2	33.9	45.9			35.6		
SB19	GLY	25.7	37.4	47.0	**36.4^{b}**			36.7	
	PRQ	20.8	31.8	43.3					32.0
	C	40.6	47.6	50.3		46.2			
	2,4-D	34.5	40.3	50.9			41.9		
SB25	GLY	32.6	36.7	47.9	**40.5^{a}**			39.1	
	PRQ	26.2	34.8	44.2					35.1
Herbicides Means						**41.1^{a}**	**38.2^{b}**	**37.4^{b}**	**33.4^{c}**
Stage means		**30.5^{c}**	**37.6^{b}**	**44.5^{a}**					
CV % 5.5									
S.E. D 3.1									

Means followed by the same letter(s) are not statistically different at 5 % level of probability. R6, R7 and R8 are the stages of herbicides application. C – control, 2, 4-D – 2,4-Dichlorophenoxyacetic Acid, GLY – Glyphosate, PRQ – Paraquat.

Significant difference ($P \leq 0.05$) on seed size among the cultivars was recorded at Busia. Cultivar SB25 with seed size of 46 mm² was significantly bigger compared to SB19 with 40 mm² and SB3 with 39 mm². The two cultivars SB19 and SB3 were not significantly different but SB3 has the smaller seed size (Table 10). No significant difference was observed on seed size due to herbicides application. However, control was bigger as it had seed size of 43mm² followed by 2,4-D and GLY with equal seed size of 42 mm² and PRQ had the smaller seed size of 40 (Table 10). Also, significant differences ($P \leq 0.001$) on seed size due to application stages was observed. The stage R8 had bigger seed size of 45 mm²followed by R7 with 43 mm² though, not significantly different but differed significantly from R6, which had smaller seed size of 38 mm² (Table 10).

Table 10. Effect of soybean cultivars, herbicides and application stages on seed size (mm²) at Busia

Cultivars	Herbicides	Stages			Cultivar mean	Herbicides			
		R6	R7	R8		C	2,4-D	GLY	PRQ
	C	36.8	40.4	42.6		40.1			
	2,4-D	35.9	40.5	43.6			40.1		
SB3	GLY	38.4	42.5	38.0	**39.2^{b}**			39.6	
	PRQ	31.5	41.3	39.3					37.4
	C	36.6	42.6	43.7		41.1			
	2,4-D	33.6	45.1	44.8			41.2		
SB19	GLY	37.9	40.7	40.3	**40.2^{b}**			39.6	
	PRQ	33.8	38.3	45.4					39.2
	C	44.4	50.4	52.7		49.2			
	2,4-D	43.6	38.0	50.0			43.9		
SB25	GLY	40.1	46.8	48.7	**45.9^{a}**			45.2	
	PRQ	39.0	47.8	49.4					45.4
Herbicides Means						**44.4^{a}**	**41.6^{a}**	**41.5^{a}**	**40.6^{a}**
Stage means		**37.6^{b}**	**42.9^{a}**	**44.9^{a}**					
CV % 11.0									
S.E. D 3.9									

Means followed by the same letter(s) are not statistically different at 5 % level of probability. R6, R7 and R8 are the stages of herbicides application. C – control, 2, 4-D – 2,4-Dichlorophenoxyacetic Acid, GLY – Glyphosate, PRQ – Paraquat

DISCUSSION

The cultivar SB19 produced higher seed yield at UoE. This higher yield was attributed to its inherent ability of wide adaptation to different environmental conditions (TSBF-CIAT soybean data, unpublished). However lower yield of SB25 was also due to its poor adaptation to the cold environment and being late maturity because it only grows vegetatively. The SB3 which was genetically higher yielder also was outperformed by SB19 due its poor adaptation.

The cultivar SB19 also had highest yield at Mabanga and SB3 had lowest yieldwhich was due to poor adaptation to the site and being short type cultivar. This made it stunted in growth with few branches and fewer pods. At Busia though, the cultivars were not significantly different in yield, similar trend was also noticed with highest yield in SB19 and lowest in SB3.

This finding is similar to that of Tariq *et al*. (2017) in which they also reported significant variations in yield of soybean, with cultivars Williams – 82which had more seed yield than Swat – 84. This could also be due to its wide adaptation as with SB19 because theywere planted at different locations. It is also in agreement with results showed by Evans (1996) who also reported that, the genotypes had a significant effect on seeds yield. Yari *et al*. (2013) also reported significant differences on seed yield higher, by cultivar Williams compared to others. Similar result was also reported by Rehman *et al.* (2014) on yield among the soybean cultivars they tested. The seed yield in this study was also found to correlates with number of pods per plants, seed size and TSW.

Herbicides application was observed to influence seed yield in all the sites. Similar trends in all the sites were observed as control yielded higher and paraquat produced lower yield. This indicated that herbicides application is detrimental to the seed yield. This result is contrary to the finding of Marchiori *et al*. (2002) who found no reduction in seed yield of canola. Lower yield of paraquat treatment was due to its quick desiccation effect because, it inhibits biochemical processes(Senseman, 2007). Rapid wilting and desiccation occur within few hours of paraquat application in full sunlight. Similar results were reported for the lower yield of paraquat and glyphosate on different crops. Eastin (1980) observed that rice head yield was reduced when diquat and paraquat were applied seven days before harvest. Paraquat in combination with sodium chlorate applied 5 to 7 d prior to harvest generally increased harvestability but did not consistently increase soybean yield (Griffin *et al.,* 2003). Azlin (1981) also reported reduction in Soybean yields when glyphosate was applied at 23 to 29 days before harvest.

Seed yield was also influenced by the application stages in all locations. The seed yield increased with the increased in stage of application as R8 predominantly higher in yields across the locations. This is attributed to the attainment of full maturity for the seed compared to R6 in which the seed were still green and R7 was the beginning of physiological maturity. Similar results were reported by (Basso *et al*., 2016; Ratnayake and Shaw, 1992). According to Peluzio *et al.* (2008) the difference can also be associated with the fact that at R6 and R7, the plants were still translocating assimilates to seed. As such, desiccation at those stages leads to standstill of supply and consequently decreased productivity. Within this same line of study, Lamego *et al.* (2013) found reduction in soybean grain yield with desiccation held at R7.1 stage, increased reduction was observed when desiccation occurred in the R6 stage.

The significant interaction of cultivar and stage at UoE on seed yield was linked to large difference between SB19 and SB3 to SB25 and the effect of spraying at R6 compared to R8. Moreover, that of herbicides and stage was associated to large difference between control and paraquat and that of spraying at R6 compared to R8. It was also reported that, soybean yield can be reduced by the use of desiccants when the application occurs before the physiological maturity Lamego *et al*. (2013), in indeterminate growth habits of cultivars, the pods are still being formed after the physiological maturity and it is recommended that the desiccation takes place after stage R8 (Zagonel, 2005). Conversely, Guimarães *et al*. (2015) had observed that preharvest desiccation prior to physiological maturity (R6) had no effect on seed yield.

Differences on the TSW among the soybean cultivars was observed at UoE, with cultivar SB19 higher and lowest in SB25. The lower weight of SB25 at UoE was related to its reduction in size due to poor adaptation to that environment. However, at Mabanga and Busia SB25 had highest weight while SB3 and SB25 were lower and statistically similar. The difference of SB25 was attributed to the initial variation in seed size since it has bigger seed size. This was confirmed by the positive correlations that exist between seed size and the TSW. This finding agreed with that of Goffnett (2015) who reported significant variation on seed weight of black beans cultivars.

Thousand seed weight was also found to be influenced by herbicides application. Similar trend was noted in all the sites as control weighted heavier and paraquat treatment had lowest weight. This also indicates that herbicides application was detrimental to seed weight. This finding corresponds to that of Habimana *et al*. (2013) in which they recorded higher 100 SW in inter cultivation followed by hand weeding plots as compared to the plots with metribuzin and imazethapyr herbicides. Desiccation treatments also had a marginal effect on 1000-seed weight (Subedi *et al*., 2017).

However, it is contrary to that of Marchiori *et al*. (2002) who found no reduction in TSW of canola and soybean. Paraquat treated plots in this study had the lower weight though not significantly different with glyphosate in all locations. This can also be associated with rapid wilting and desiccation of the soybean that occurs within few hours of application of paraquat in full sunlight. Glyphosate was also reported to reduce pod length and seed weight when used s harvest -aid in cowpea (Cole and Ceideira; 1982., Ceideira *et al*., 1985). He *et al*. (2015) also reported that, **t**he seed weight was not significantly affected bychemical applications in the rice cultivars they studied. However, they reported that, the weight decreased slightly when the application rates of diquatand paraquat were increased from 120 to 240 g/ha which was higher compared to rate used in this study as the 200g/ha of paraquat was used. .
This study also revealed variation on TSW due to different application stages in all locations. The TSW also increased with the increased in stage of application, with R8 predominantly showing higher weight across the locations. This is attributed to the attainment of full maturity for the seed compared to R6 in which the seed were still green and R7 was the beginning of physiological maturity. Similar results were reported by (Basso *et al*., 2016; Ratnayake and Shaw, 1992; Lamego *et al*., 2013).Hundred seed weight was also reported to be influenced by time of desiccant application as reported by (Pinto *et al*., 2014).

The herbicides and stage interactions on TSW observed in this study was associated to wide difference between control and other herbicides especially that of control and Paraquat and

the spraying at R6 compared to R8. However, the interaction of variety and stage was associated to the difference in weight of SB25 to SB3 and the effect of spraying at R6 and R7 compared to R8. Significant interaction between herbicides and stage of application was also reported by Bellé *et al*. (2014). Bennett and Shaw (2000) also reported significant interaction between varieties and stage of herbicides application in soybean. They noted that, when desiccants were applied at either R5, R6 or R7 to the two cultivars they evaluated, seed weight was reduced as the stage of application reduced from R8.

The smaller size of SB25 at UoE was due to its poor adaptation in that environment. However, it was bigger in size than SB19 and SB3 at Mabanga and Busia, as it was observed on thousand seed weight. The differences were associated to the inherent genetic factor and that of environmental adaptation of the cultivars. This also corroborate with the yield and other yield attributes as it was shown in correlation table. Initial seed size has been recognized as one of the factors that influence yield of soybean (Smith and Camper, 1975). While some field trials have shown that plants from large seeds had significantly greater yield than those from small seeds (Smith and Camper, 1975; Fontes and Ohlrogge, 1972; Burris, 1973).

Based on herbicides application control plots predominantly showed bigger seed size compared to paraquat treatments. This could be associated to the fact that the growth/and development of the control was not interfered with at all. It was reported by Subedi *et al.* (2017) that glyphosate applied alone or as a tank mix with other herbicides had no significant effect on seed diameter, thickness, or seed plumpness. Conversely, application of higher rates of contact herbicides significantly decreased seed diameter. They added that, neither addition of contact herbicide with glyphosate nor glyphosate applied alone affected seed thickness or plumpness.

Bigger seed size predominantly shown by R8 across the locations is attributed to the attainment of full maturity for the seed compared to R6 and R7.

CONCLUSION

This study showed that, seed yield was reduced due to herbicides application on the soybean cultivars. The cultivars SB19 was less affected and among the herbicides treatments, 2-4D had highest yield while paraquat had lowest yield. The application stages also had influenced on seed yield. The seed yield increased with the increased in stage of application as stage R8 was predominantly higher. Similarly seed weight and size were also reduced due to herbicides and the stages at which application was done. It is recommended that; extra-early varieties should be planted so as to avoid the effect of herbicides on the parameters measured.

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