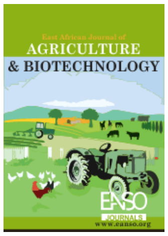

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Original Article

The Influence of Plant Spacing and Weed Control Intervals on Weed Infestation, Growth and Yield-Related Traits of TGX 2010- 2F Soybean (Glycine max L.) Variety in Buea, Cameroon

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Plant Spacing, Weeding Interval, TGX 2010-2F Soybean, Growth, Yield.

ABSTRACT

Achieving optimal soybean productivity requires careful consideration of several key agronomic factors. Field trials were carried out in the Teaching and Research Farm of the Faculty of Agriculture and Veterinary Medicine, University of Buea, during the 2022 and 2023 cropping seasons to assess the effect of plant spacing and weeding intervals on weeds, growth components, and yield of TGX 2010- 2F soybean variety. A 4x4 factorial combination of four plants spacing (30cm x 20cm, 30cm x 30cm, 40cm x 30cm, and 75cm x 50cm) and four weeding intervals (one-hand weeding at two weeks after sowing (WAS), one-hand weeding 3WAS, one-hand weeding 4WAS and one-hand weeding 5WAS) were laid out in a randomised complete block design with three replications. Analysis of variance for lumped data for the 2 years revealed that plant spacing significantly (P<0.05) influenced plant height, number of branches, stem girth, number of pods, grain yield, and weed components while weeding intervals significantly influenced all the soybean growth components, grain yield, and all weed parameters. The interaction effect of plant spacing and weeding intervals had significant (P<0.05) impacts on the number of branches, stem girth, grain yield, and weed parameters. The most abundant weed families were the Poaceae (03) and Asteraceae (03), followed by the Lamiaceae (02), Amaranthaceae, Brassicaceae, and Oxalidaceae, each of which recorded one species. Significantly higher plant height (28.68±1.7cm), number of pods (87.08 ± 6.26/m^2), and grain yield (3.48±0.29 tons/ha) were observed under 30cm x 20cm plant spacing. Additionally, higher weed fresh weight of 769.30±92.3 g/m^2, weed dry weight of 748.90±92.3 g/m^2 and weed biomass of 0.46±0.06 tons/ha and the lowest grain yield of 2.04±0.28 tons/ha were recorded under one-hand weeding at 5WAS treatments. The highest grain yield, 4.38±0.03 tons/ha, was obtained from the interaction of 30cm x 20cm plant spacing and one-hand weeding 2WAS treatments. These results suggest that narrow plant spacing of 30cm x 20cm and practicing one-hand weeding at 2WAS will improve the productivity and reduce labour, thus making it agronomically feasible for TGX 2010-2F soybean production.

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INTRODUCTION

Famously called the "king of beans," soybeans are among the most protein-rich legumes, with a protein content ranging from 36% to 40%. They play a vital role in global protein consumption, contributing directly and indirectly (Vivek et al., 2024). Soybeans also account for a large portion of oil consumed globally, making them vital for both nutritional and industrial uses (Zhu et al., 2023; Gustavo et al., 2024).

Soybeans have a substantial economic impact, contributing approximately USD 155 billion to the global economy (Vivek et al., 2024). Soybean farming in Sub-Saharan Africa, particularly Cameroon, has grown dramatically in recent years, motivated by its potential to ease food shortages, enhance rural lives, and contribute to agricultural diversification (Benjamin & Abraham, 2022; Vincent et al., 2025). Additionally, they contain bioactive compounds such as isoflavones, which are associated with numerous health benefits, including a reduced risk of heart disease and cancer (Messina et al., 2022). The versatility of soybeans allows them to be processed into oil, soy milk, and various meat alternatives such as "soybean soya" in Cameroon (Solefack et al., 2024). Soybeans also improve soil health through nitrogen fixation and are often used in crop rotation systems (Albahri et al., 2023; Parastoo et al., 2024).

Obtaining optimal soybean productivity necessitates careful consideration of several agronomic aspects, especially in places with distinct soil and climate conditions. Buea is known for its volcanic soils, which are naturally rich in minerals and organic matter, but poor management practices might undermine their high productivity potential (Tening et al., 2013). Plant spacing and weeding intervals are important practices that affect soybean development and output (Imoloame et al., 2013; Daramola, 2020). Planting distance determines the spatial arrangement of plants in the field. It influences resource availability, competition, and crop canopy structure (Daramola et al., 2019; Haarhoff et al., 2022). For instance, 45 plants/m^2 in Kenya (Misiko et al., 2008) and 40 plants/m^2 in Ethiopia (Worku & Astatkie, 2010) were the ideal plant densities reported for higher soybean output. In contrast, poor spacing can result in lower growth and output due to overpopulation or underutilisation

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of resources. On the other hand, proper weed control constitutes one of the most critical and costly processes in soybean production (Stefanic et al., 2022). Uncontrolled weed growth can drastically lower soybean yields, especially in the early stages of crop development (Benjamin et al., 2020). Excessive weeding may increase labour expenses and soil disturbance, negatively influencing fertility. Balancing these elements is critical for achieving high yields and sustainable production systems (Pagano & Miransari, 2016).

The choice of soybean variety is crucial for profitable farming (Chigeza et al., 2019; Johann, 2023). Variety performance varies by location due to factors such as plant spacing and weather (Lum et al., 2019; Eseigbe et al., 2024). The TGX 2010-2F variety shows potential for yield and tolerance in tropical climates (Tefera, 2011). However, its effectiveness in Buea's volcanic soils, considering interactions between plant spacings and weeding intervals, has not yet been studied. This research aims to develop site-specific production recommendations for TGX 2010-2F by examining these factors in volcanic soils. The results will enhance productivity, improve soybean farming methods, and support sustainable agriculture and food security in the region. Additionally, the findings will benefit local farmers in Buea and inform initiatives to expand soybean cultivation in similar agroecological zones across Sub-Saharan Africa.

MATERIALS AND METHODS

Description of the Study Area

The research was conducted at the Teaching and Research Farm of the Faculty of Agriculture and Veterinary Medicine, University of Buea, in the South West Region of Cameroon, during the 2022 and 2023 cropping seasons. Buea is situated in agroecology zone IV of Cameroon and falls between latitudes 4º3'N and 4º12'N of the equator and longitudes 9º12'E and 9º20'E. The soil type is derived from weathered volcanic rocks, and the dominance of silt with 51.6% (31.1 fine silt and 20.5 coarse silt), followed by clay with 42% and sand with 6.4% (Tening et al., 2014). The climate in this area is tropical maritime and equatorial. It receives an average annual rainfall of 2500–3500 mm, an average annual temperature of 26 ºC, and a relative humidity of 75–80% throughout the year.

Treatments and Design

A 4 × 4 factorial experiment was conducted, comprising four plant spacingsT1: 75cm x 50cm, T2: 40cm x 30cm, T3: 30cm x 30cm, and T4: 30cm x 20cm and four levels of weeding intervals; WF1: hand weeding at 2 weeks after sowing (WAS), WF2: hand weeding at 3WAS, WF3: hand weeding at 4WAS and WF4: hand weeding at 5WAS, resulting in 16 treatment combinations. The experiment was arranged in a randomized complete block design (RCBD) with three replications. The total experimental area was 22 m × 59 m (1,298 m²), with each net plot measuring 16 m² (4 m × 4 m).

Experimental Procedures and Management of the Experimental Plots

The field was prepared by ploughing and harrowing with a tractor, followed by the formation of raised beds using a hoe two weeks later. The TGX 2010-2F soybean variety, sourced from IITA, Yaoundé, was used. Sowing was performed manually in April of both 2022 and 2023, placing three seeds per hill at a depth of 5 cm. Two weeks after sowing (WAS), seedlings were thinned to two per stand, retaining only the most vigorous plants. Standard agronomic practices were uniformly applied across all plots. Weeding was conducted according to the assigned treatment intervals. The weeds encountered on the field before the study included annual broad leaves: *Emilia coccinea*, *Bidens Pilosa*, *Commelina diffusa*, *Amaranthus spinosus*, *Euphorbia hirta*, *Perilla frutescens*, *Ageratum conyzoides*, *Oxalis barrelieri*, *and Camelina sativa*. Perennial grasses included *Cynodon dactylon*, *Momordica dioica*, *Lolium perenne,* and a sedge, *Cyperus alopecuriodes.*

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Data Collection

Rainfall and temperature recorded during the cropping season in both years were 2000mm and 26 ºC, respectively, although rainfall was sporadic.

In both years, observations on soybean attributes such as plant height (cm plant^{-1}), number of leaves, stem girth (cm), and leaf area were recorded per square metre within the net plot at V6 (final number of trifoliate leaves developed). The stem girth was measured with a vernier calliper following the procedure outlined by Stefanic et al. (2022). The leaf area per plant was calculated following the method described by Daramola et al. (2020), Eqn. (1):

A = LW……………………………………… (1)

Where A is the leaf area and L and W are the length and width of the terminal leaflet.

The yield components, such as the number of pods and 1000-seed weight, were recorded per square metre within the net plot of each treatment at R8 (full maturity). The grain yield (tons/ha) (Eqn. 2) was obtained after threshing the plants in each plot and drying them in an oven at 60 °C for 76 h. The resulting seed weight, in kg plot^{-1} at 12 % moisture content, was expressed in kg ha^{-1}.

Grain yield = grain weight per net plot (kg) × ((100 − MC)/88) × (10,000 m^2)/7.5 m^2 … (2)

Where MC = Moisture content

Data on weed species, weed density (Eqn. 3), and weed dry matter were collected at 2,3,4, and 5 WAS in both years using a 40 cm × 40 cm quadrat placed 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 (Fickett et al., 2013).

$$\text{Density} = \frac{\text{Number of individuals sampled}}{\text{Area sampled}}$$
……………………………………………… (3)

The Shannon-Weiner index and Simpson diversity (Shannon and Weaver, 1963) were used to estimate the weed species richness and diversity.

Data Analysis

Data collected for both the 2022 and 2023 seasons were pooled for analysis. Data collected were entered into MINITAB Version 13 Statistical Package (MINITAB Inc., PA, USA). The data were then subjected to the Kolmogorov–Smirnov test for normality, while Levene's test was conducted for heterogeneity of variance. Data that did not meet these conditions were Box-Cox transformed. Two-way analyses of variance (ANOVA) were conducted following the General Linear Model approach. The effects of factors and their interactions were assessed at $\alpha = 0.05$. Means were separated using Tukey HSD. Means and standard errors were computed for presentation.

RESULTS

Effect of Plant Spacing and Weeding Intervals on the Growth of Soybeans

Analysis of variance for the combined data from both years showed that plant spacing significantly ($P < 0.05$) influenced plant height, number of branches, and stem girth. (Table 1). The narrowest spacing (30 cm × 20 cm) produced the tallest plants, with an average height of 28.68 ± 1.45 cm, while the 40 cm × 30 cm spacing resulted in the shortest mean plant height (26.6 ± 1.7 cm; Table 1). Regarding weeding intervals, plots weeded at 2 weeks after sowing (2WAS) had the lowest average plant height (11.78 ± 0.27 cm), whereas those weeded at 5WAS reached the highest average height (45.35 ± 1.0 cm). The number of leaves per plant increased substantially from 7.5 ± 0.08 at the earliest weeding interval to 70.54 ± 1.30 at 5WAS, indicating vigorous vegetative growth with delayed weeding. Also, the highest number of branches (2.08 ± 0.23) was recorded under the 40cm x 30cm spacing and the lowest number (1.71 ± 0.21) under the 75cm x 50cm spacing. Similarly, the number of branches at the one-hand weeding 5WAS weeding interval was

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4.42 ± 0.09 up from 0 branches at the first two weeding intervals (Figure 1). The thickest stem girth (1.81 ± 0.11 cm) was noted in the 30cm x 30 cm spacing and the thinnest girth (1.43± 0.09cm) was noted under the 75cm x 50cm spacing (Table 1). Meanwhile, stem girth increased from 0.51 ± 0.01 cm at the first weeding interval to 2.8 ± 0.05 cm at the fourth weeding interval (Fig. 1). Leaf area ranged from 46.32 ± 3.43 cm^2 to 49.33 ± 3.59 cm^2 under the different spacings and increased from 12.08 ± 0.22 cm^2 at the first weeding to 87.7 ± 1.87 cm^2 at the one-hand weeding 5WAS interval.

The interaction effect of spacing and weeding interval only had significant ($P<0.05$) effects on the number of branches and stem girth with the highest number of branches (4.58 ± 0.15) obtained at the one-hand weeding 5WAS interval in plants of the 40cm x 30cm spacing and treatment branching following the sigmoid growth curve as expected for healthy plants (Fig. 2).

Table 1: The Effect of Planting Spacing on the Growth Characteristics of Soybeans

Spacing	Plant height (cm)	No. of leaves	No. of branches	Stem girth (cm)	Leaf area
30x20 cm	28.68±1.7c	30.99±2.61a	1.88±0.23ab	1.64±0.1b	49.33±3.59a
30x30 cm	27.97±1.47b	32.08±2.87a	2.07±0.23a	1.81±0.11a	46.68±3.35a
40x30 cm	26.6±1.45a	33.06±2.88a	2.08±0.23a	1.77±0.1a	46.78±3.21a
75x50 cm	26.7±1.44a	33.36±2.62a	1.71±0.21b	2.43±0.09c	46.32±3.43a
p-value	0.001	0.095	0.000	0.000	0.129
df	3	3	3	3	3

Values in the table represent means ± Standard error. Means separated through GLM ANOVA with Tukey HSD test at α = 0.05. Means with the same letter within the column are not statistically different.

Figure 1: Response of Soybean to the Main Effect of Weeding Intervals on Its Growth Components

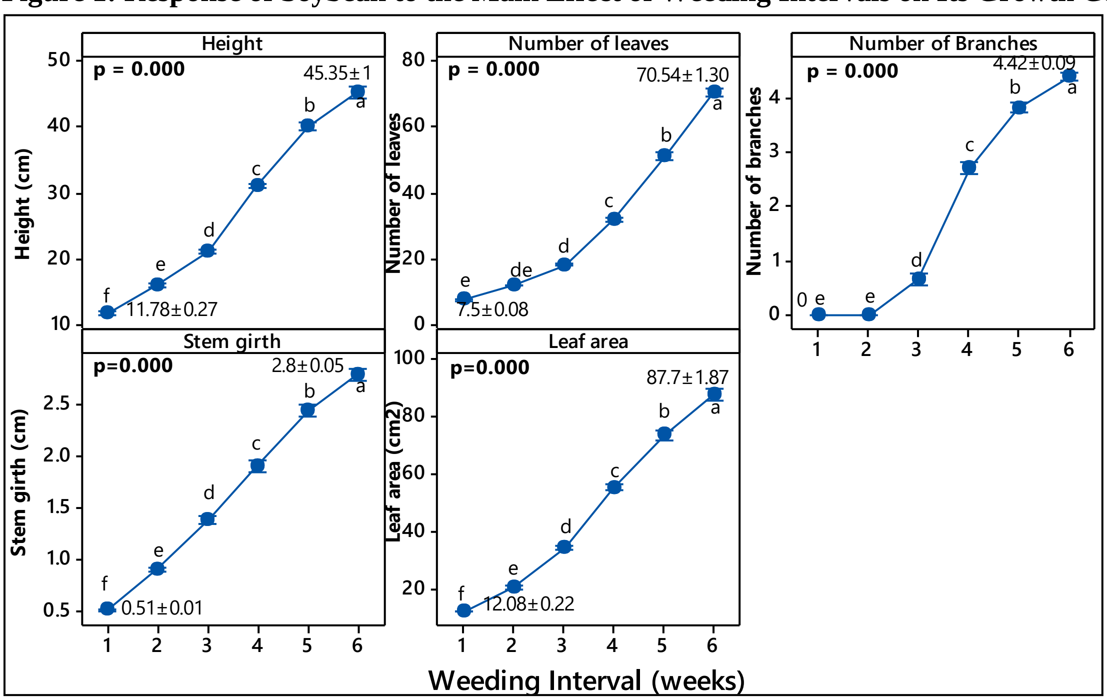

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Figure 2: Interaction Effects of Plant Spacing and Weeding Intervals of Soybean on the Number of Branches and Stem Girth.

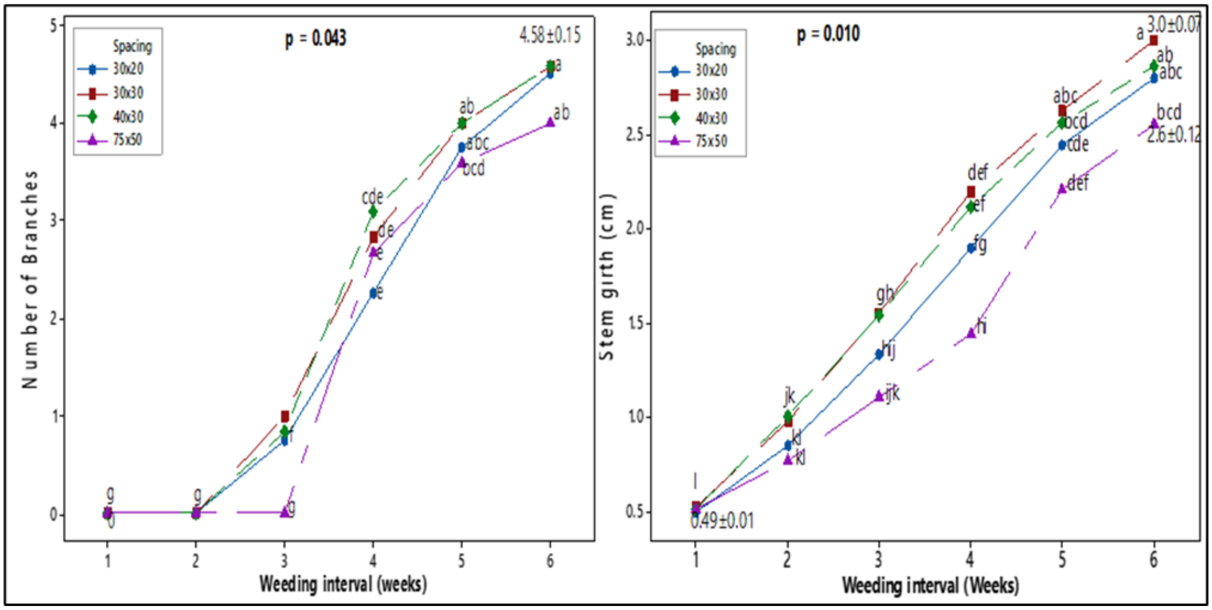

Table 2 presents the results of the correlation of factors (plant spacing and weeding intervals) with soybean growth response variables. Statistical analysis revealed strong positive correlations between the weeding interval and all measured growth variables, as well as among the growth variables themselves, indicating consistent internal relationships. In contrast, there was a weak but statistically significant negative correlation between plant spacing and stem girth (r = -0.142, P = 0.016), suggesting that wider spacing slightly reduced stem thickness.

Table 2: Correlation of Plant Spacing and Weeding Interval with Soybean Growth Parameters

	Weeding Interval	Spacing	Height	Number of leaves	Number of branches	Stem girth
Plant spacing	0.000					
	1.000					
Height	0.953	-0.011				
	0.000	0.859				
Number of leaves	0.940	-0.007	0.944			
	0.000	0.903	0.000			
Number of Branches	0.918	-0.061	0.924	0.919		
	0.000	0.301	0.000	0.000		
Stem girth	0.938	-0.142	0.918	0.908	0.906	
	0.000	0.016	0.000	0.000	0.000	
Leaf area	0.951	-0.024	0.933	0.919	0.901	0.895
	0.000	0.681	0.000	0.000	0.000	0.000

Values in the top cell represent r, the Pearson Correlation Coefficient; values in the bottom cell represent p-values, the level of significance. Correlations exist where p-values are less than 0.05.

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Effect of Plant Spacings and Weeding Intervals on Soybean Yield

Table 3 shows that the narrowest spacing (30cm x 20cm) produced both the highest number of pods (87.08 ± 6.26) and the greatest grain yield (3.48 ± 0.29 tons/ha). In contrast, the widest spacing (75cm x 50cm) resulted in the lowest pod count (64.67 ± 6.67) and yield (0.79 ± 0.04 tons/ha). Weeding interval significantly influenced grain yield (Table 5). Additionally, the interaction of plant spacing and weeding interval significantly affected soybean grain yield (Table 6). The combination of 30 cm × 20 cm spacing and one-hand weeding at 2WAS resulted in the highest grain yield (4.38 ± 0.03 tons/ha), while the lowest yield (0.65 ± 0.03 tons/ha) was recorded for the 75 cm × 50 cm spacing with weeding at 5WAS.

Table 3: Main Effect of Plant Spacing on Soybean Yield

Factor	Number of pods/m^2	1000 seed weight (g)	Grain Yield (tons/ha)
Spacing			
30x20 cm	87.08±6.26a	116.52±0.81a	3.48±0.29a
30x30 cm	86.00±7.83a	114.70±0.55a	3.21±0.26a
40x30 cm	82.00±6.26a	115.65±0.29a	2.32±0.19b
75x50 cm	64.67±5.01b	117.34±2a	0.79±0.04c
p-value	0.020	0.373	0.000

Values in the table represent means ± Standard error. Means separated through GLM ANOVA with Tukey HSD test at α = 0.05. Means with the same letter within the column are not statistically different.

Effect of Plant Spacing and Weeding Intervals on Weeds in the Soybean Cropping Field

The experimental fields were infested with weeds, including broad-leaved, sedges, and grass weeds, with a majority being annual herbaceous weeds (Table 4). A total of 16 weed species from 12 botanical families were identified in the experimental fields. The Poaceae and Asteraceae families were the most represented, each with three species, followed by Lamiaceae with two species. Amaranthaceae, Brassicaceae, and Oxalidaceae each contributed one species (Table 4).

Table 4: Inventory of Weed Species in Soybean Experimental Field During the Cropping Season.

S/N	Common name	Sc. Name	life	Family
1	Spiny amaranth	*Amaranthus spinosus* (A)	Annual herb	Amaranthaceae
2	red thistle	*Emilia coccinea* (A)	Annual herb	Asteraceae
3	Blackjack	*Bidens pilosa* (A)	Annual herb	Asteraceae
4	Cardamine	*Cardamine hirsute* (b)	Annual herb	Brassicaceae
5	False flax	*Commelina sativa* L (a)	Annual herb	Commelinaceae
6	King grass	*Agerantum conyzoides* (A)	Annual herb	Asteraceae
7	Spine gourd	*Momordica dioica* (A)	Perennial herb	Cucurbitaceae
8	Cyperus	*Cyperus alopecuriodes* (A)	Sedge	Cyperaceae
9	Asthma plant	*Euphorbia hirta* L (a)	Annual herb	Euphorbiaceae
10	Spear grass	*Heteropogon contortus* (b)	Annual herb (broad leaf)	Lamiaceae
11	Perilla mint	*Perilla frutescens* (a)	Annual broadleaf	Lamiaceae
12	Barrelier’s woodsorrel	*Oxalis barrelieri* (A)	Annual woody herb	Oxalidaceae

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S/N	Common name	Sc. Name	life	Family
13	Bahalma grass	*Cynodon dactylon* (b)	Perennial grass	Poaceae
14	Rough blue grass	*Lolium perenne* L (a)	Perennial grass	Poaceae
15	Velvet bean	*Mucuna pruriens* (b)	Perennial grass	Poaceae
16	Common Indian parselane	*Portulaca oleracea* (b)	Annual herb	Portulacaceae

(A)= weeds that appeared in the pre- and post-collection. (a)= weeds in pre-collection only. (b)= weeds in post collection only.

Statistical analysis of the data showed that different treatments significantly ($P<0.001$) affected the weed density and weed biomass (fresh, dry, and total) (Table 5). Maximum weed density (46.25 ± 1.81 plants/m²) was observed at the widest plant spacing (75 cm × 50 cm), while the highest weed density for weeding interval was recorded at 5WAS (48 ± 2.87 plants/m²). The greatest weed fresh weight, dry weight, and total biomass (0.52 ± 0.05 tons/ha) were also found in the 75 cm × 50 cm plots, whereas the lowest total weed biomass (0.25 ± 0.02 tons/ha) occurred at the narrowest spacing (30 cm × 20 cm). The weeding at 5WAS recorded the highest weed biomass (0.46 ± 0.06 tons/ha) while the one-hand weeding interval at 2WAS had the lowest biomass (0.21 ± 0.01 tons/ha).

Furthermore, the interaction of plant spacing and weeding intervals significantly ($P<0.01$) influenced weed density, fresh and dry weights, and total weed biomass (Table 6). The highest weed density (52±1.15 m^{-2}) was recorded at the spacings of 30cm x 20cm and 30cm x 30cm during the fourth weeding 5WAS. The highest weed fresh weight (1,118.7 ± 2.89 g/m^2), dry weight (1,098.7 ± 2.89 g/m^2), and total biomass (0.68 ± 0.01 tons/ha) were recorded in the 75 cm × 50 cm plots at the 5WAS weeding interval. In contrast, the lowest total weed biomass (0.18 ± 0.01 tons/ha) was found in plots with 30 cm × 20 cm spacing and weeding at 2WAS (Table 6).

Table 5: Effect of Spacing and Weeding Frequency on Weed Biomass and Grain Yield in Plots Planted with Soybean in Buea

Factor	Weed density (m^{-2})	Weed fresh weight (g/m^2)	Weed dry weight (g/m^2)	Total Weed biomass (tons/ha)	Grain yield (tons/ha)
Plant Spacing					
30cm x 20cm	34.25± 2.46c	423.5±32.20d	401.7±31.70d	0.25±0.02d	3.50±0.10a
30cm x 30cm	33.50±0.70c	448.6±14.10c	428.5±14.10c	0.27±0.01c	3.29±0.22c
40 cm x 30cm	43.50±2.62b	717.9±76.80b	697.8±76.70b	0.43±0.05b	2.32±0.10b
75cm x 50cm	46.25±1.81a	848.0±85.10a	828.0±85.10a	0.52±0.05a	0.79±0.03d
p-value	0.00	0.00	0.00	0.00	0.00
Weeding interval (WAS)					
2	32.75±0.92c	365.30±11.2d	345.10±11.2d	0.21±0.01c	2.49±0.35b
3	41.00±1.85b	574.60±64.6c	554.20±64.6c	0.34±0.04b	2.89±0.41a
4	48.00±1.39a	728.70±64.3b	707.70±64.6b	0.44±0.04a	2.49±0.30b
5	47.15±2.87a	769.30±92.3a	748.90±92.3a	0.46±0.06a	2.04±0.28c
p-value	0.00	0.00	0.00	0.00	0.00

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Values in the table represent means ± SE. Means separated through GLM ANOVA with Tukey HSD test at α = 0.05. Means with the same letter within the column are not statistically different.

Table 6: Interaction Effects of Plant Spacing and Weeding Interval on Weed Diversity, Fresh and Dry Weight, Biomass, and Soybean Grain Yield at Harvest

Plant spacing	Weeding interval (WAS)	Weed density (m^{-2})	Weed fresh weight (gm^{-2})	Weed dry weight (gm^{-2})	Total Weed biomass (tons/ha)	Grain yield (tons/ha)
30cm x 20 cm	2	30± 1.15h	338.81±2.89k	318.18±2.89k	0.19±0.01f	4.38±0.03b
	3	38± 1.15efg	316.95±2.89l	296.59±2.89l	0.18±0.01f	3.88±0.03b
	4	52±1.15ab	585.77±2.89f	560.77±2.89f	0.35±0.01c	3.16±0.03c
	5	37±1.15fg	452.42±2.89i	431.42±2.89i	0.26±0.01de	3.19±0.03c
30cm x 30cm	2	37±1.15fg	397.49±2.89j	377.49±2.89j	0.24±0.01ef	3.24±0.03c
	3	50±1.15abc	409.37±2.89j	389.37±2.89j	0.24±0.01ef	3.76±0.03a
	4	52±1.15ab	509.62±2.89g	489.62±2.89g	0.31±0.01cd	3.17±0.03c
	5	46±1.15bcd	477.74±2.89h	457.47±2.89h	0.28±0.01de	2.38±0.03e
40cm x 30cm	2	32±1.15gh	319.43±2.89l	299.43±2.89l	0.18±0.01f	2.20±0.03f
	3	42±1.15def	769.21±2.89e	748.12±2.89e	0.46±0.01b	2.35±0.03ef
	4	56±1.15a	754.60±2.89e	735.60±2.89e	0.45±0.01b	2.80±0.03d
	5	44±1.15cde	1028.50±2.89c	1007.90±2.89c	0.63±0.01a	1.93±0.03g
75cm x 50cm	2	32±1.15gh	405.44±2.89j	385.44±2.89j	0.24±0.01ef	0.75± 0.05ij
	3	34±1.15gh	802.87±2.89d	782.87±2.89d	0.48±0.01b	0.94±0.03h
	4	32±1.15gh	1064.90±2.89b	1044.90±2.89b	0.66±0.01a	0.81±0.03hi
	5	36±1.15fgh	1118.70±2.89a	1098.70±2.89a	0.68±0.01a	0.65±0.03j
p-value		0.00	0.00	0.00	0.00	0.00

Values in the table represent means ± SE. Means separated through GLM ANOVA with Tukey HSD test at α = 0.05. Means with the same letter within the column are not statistically different

DISCUSSIONS

The results demonstrated that narrow plant spacing (30cm x 20cm) and early weeding (2 weeks after sowing) significantly improved soybean growth, yield components, and reduced weed infestation. Specifically, the highest grain yield (4.38 ± 0.03 tons/ha) was achieved with the combination of 30cm x 20cm spacing and one-hand weeding at 2WAS, while the widest spacing (75cm x 50cm) and delayed weeding (5WAS) resulted in the lowest yield and highest weed biomass. These findings highlight the agronomic advantage of narrow spacing and timely weed control for TGX 2010-2F soybean production in Buea's volcanic soils.

The increase in plant height, leaf area, number of branches, number of pods, 1000 grain weight as

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well as grain yield of soybean with the reduction in plant spacing from 75cm x 50cm to 30cm x 20cm with cumulated data may be due to reduced weed competition for growth resources (light, nutrients) with the increase in the number of plants stands. The findings corroborate the works of Lum et al. (2019) and Daramola et al. (2019), who reported that there is better use of resources at narrow plant spacing compared to wide row spacing as a result of the reduction in weed competition. While the studies of Maurya et al. (2013) and Gribaldi et al. (2024) have reported greater leaf area and plant height at wider spacings, our findings show the opposite trend. This discrepancy may be explained by increased weed competition and nutrient loss in the wide rows of our study, as well as the rapid canopy closure and competitive ability of the TGX 2010-2F variety under Buea's volcanic soil conditions (Borger et al., 2016). Wider plant spacing resulted in thicker stems due to reduced intraspecific competition, allowing each plant greater access to sunlight, nutrients, and space. However, despite producing thinner and taller stems at narrow spacing, the TGX 2010-2F variety did not exhibit lodging, indicating its structural resilience even under dense planting, supporting the findings of Cox & Cherney (2011). Narrow spacing also facilitated rapid canopy closure, which boosted not only the number of pods and 1000-seed weight but also the grain yield. This is most likely owing to better light interception and photosynthetic efficiency at critical growth stages, as well as reduced weed competition; findings that are consistent with Lu et al. (2020).

The observed weed community is representative of the normal weed spectrum in Buea's soybean fields, with annual grasses and broadleaf species from Poaceae and Asteraceae predominating (Ndam et al., 2025). According to Mengesha et al. (2015), these weeds are known to actively compete with soybeans for resources, and their prevalence highlights the necessity of efficient management techniques, including timely weeding and optimal plant spacing. Management practices and environmental conditions (soil type, altitude, and previous crops grown at the sites) affect soybeans and the distribution of weed species (Bana & Getachew, 2022). As one of the management strategies, the manipulation of plant spacing can significantly affect weeds in soybean fields (Stefanic et al., 2022). However, our results suggest that management factors play more important roles than environmental ones. The rainfall during the growing seasons of 2022 and 2023 was sporadic, requiring irrigation. Different crop types and their associated management have more influence on weed composition than the relative importance of climatic variables (Fickett et al., 2013).

Generally, weeds are better competitors for edaphic resources than crop plants and would do well where they have less competition (Fahad et al., 2015). Wider spacing (75cm x 50cm) and delayed weeding (5WAS) resulted in the highest weed density and biomass, corresponding to the lowest soybean yield. In contrast, narrow spacing (30cm x 20cm) and early weeding (2WAS) minimised weed growth and maximised yield, likely due to rapid canopy closure and reduced light availability for weeds. This supports the findings of Tursun et al. (2016), Adigun et al. (2017), Jha et al. (2017), and Hassain et al. (2022), who demonstrated that higher plant populations and timely weed control are effective non-chemical strategies for weed suppression and yield improvement.

The findings of this study suggest that adopting narrow plant spacing and early weeding can enhance productivity and reduce labour for smallholder farmers in Cameroon. However, in addition to physical competition, soybeans may suppress weeds through allelopathic effects, releasing phenolic compounds such as trans-cinnamic acid and ferulic acid that inhibit weed germination and growth (Cheng & Cheng, 2015; Hassain et al., 2022). While this mechanism has been documented in other varieties (Mahmoodzadeh and Mahmoodzadeh, 2013), the study did not assess the allelopathic potential of the TGX 2010-2F variety, nor did it explore long-term

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impacts on soil health. Future research should investigate these aspects to further optimise soybean management strategies.

CONCLUSION

Weed competition is a significant constraint to optimal soybean production. This study clearly shows that adopting a narrow plant spacing of 30 cm × 20 cm, combined with a single hand weeding at two weeks after sowing (2WAS), significantly enhances early crop vigour, suppresses weed growth, and leads to the highest grain yield in TGX 2010-2F soybean under the conditions tested in Buea, Cameroon. Implementing this strategy can help farmers achieve better weed control and higher yields while reducing the need for repeated manual weeding, thus lowering labour costs, a key advantage for smallholder and resource-limited farmers. While this study provides practical recommendations for TGX 2010-2F soybean production, further research is needed to evaluate the allelopathic effects of this variety and to assess long-term impacts on weed dynamics and soil health."

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