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Influence of Supplementary Hoe Weeding on the Efficacy of Pre-emergence Herbicide on Groundnut (*Arachis Hypogea* L.) Weed Management in Bauchi, Nigeria

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Abstract: *Field experiments were conducted during rainy seasons of 2018, 2019 and 2020 at Abubakar Tafawa Balewa University Teaching and Research Farm, Gubi, to evaluate the influence of supplementary hoe weeding on the efficacy of pre-emergence herbicide and weed management of groundnut (Arachis hypogea L.) varieties. The trial comprised of ten (10) weed control treatments and three varieties of groundnut which were replicated three (3) times in a split plot design. Data were collected on weed attributes such as weed control index, treatment efficiency index, crop resistance index and weed index as well as on crop parameters such as plant height, number of branches, canopy spread, 100 kernel weight, pod yield, haulm yield and shelling percentage. Findings from the study indicated that weed parameters such as weed control index, treatment efficiency index and crop resistance index were significantly lower under the application of pendimethalin at 2.0 kg a.i.ha^{-1} fb SHW at 6 WAS and hoe weeding at 3 and 6 WAS compared to weedy check that resulted in higher value. The plant height, number of branches, canopy spread, number of pods plant^{-1} were significantly higher with the application of hoe weeding at 3 and 6 WAS, pendimethalin at 2.0 kg a.i.ha^{-1} fb SHW at 6 WAS, pendimethalin at 1.5 kg a.i.ha^{-1} fb SHW at 6 WAS. SAMNUT 22 and SAMNUT 23 varieties (P ≤ 0.01) significantly produced taller plants with a greater number of branches, canopy spread and number of pods plant^{-1}. From the findings of the trials, it can be deduced that application of supplementary hoe weeding at 6 WAS increased the efficacy of the pre-emergence herbicide viz-pendimethalin at 2.0 and 1.5 kg a.i.ha^{-1} fb SHW at 6 WAS and butachlor at 2.0 and 1.5 kg a.i.ha^{-1} fb SHW at 6 WAS. Thus, it can be adopted by farmers in the study area in place of the 2-3 manual weeding's that is usually scarce during peak periods alongside SAMNUT 22 or SAMNUT 23 to boost groundnut seed and haulm yield.*

Key words: *hoe weeding, efficacy, pre-emergence herbicide, groundnut, weed management*

INTRODUCTION

Groundnut (*Arachis hypogea* L.) is a major food and oil seed crop grown in West Africa's diverse agro-climatic environments by small-scale, resource-limited farmers (AICC, 2016). Africa

accounts for approximately 90% of global production, with the semi-arid tropics (SAT) accounting for approximately 60% of global production capacity (Vara Prasad *et al*., 2011). Nigeria ranks third in production, trailing only India and China, with 3.0, 6.9, and 13.7 million metric tons, respectively (FAOSTAT, 2016; 2017; ICRISAT, 2019). Groundnut yields in Africa have historically been low due to unpredictable rainfall patterns, insufficient technological innovations available to resource poor and small-scale farmers, prevalence of pest and disease incidence, poor seed varieties, and increased cultivation on marginal land, among other factors (Alemayehu *et al*., 2014; Debele and Amare 2015; Desmae and Sones, 2017). According to Vigueira *et al*. (2013) and Stewart (2017), weed infestation is the most significant constraint causing tremendous reductions in crop yields globally, and they have evolved to exploit croplands through a variety of different mechanisms that confer strong adaptive and competitive abilities. Weeds are estimated to account for one-third of all yield losses (34%), more than animal pests and plant pathogenic organisms (18% and 16%, respectively) (Zimdahl, 2004; Stewart, 2017), resulting in an annual crop loss and weed control cost of USD 33 billion in the United States (Lewellyn *et al*., 2016; Chauhan, 2020). The crop is heavily infested with various weed species as a result of less canopy cover during the first six weeks of its growing cycle, which if left unchecked can result in a 51% reduction in yield potential (Etejere *et al*., 2013). Several scientists have reported various weed control measures in groundnut, including manual hoe weeding, mechanical, chemical, and the integrated approach (Jat *et al*., 2011; Patel *et al*., 2013; Kaur *et al*., 2014). Manual hoe weeding, the most common method used by resource-poor farmers, has a number of drawbacks, including drudgery, crop stand loss, and labor shortages during peak periods (Abbas *et al.,* 2009; Moss, 2019). With the use of herbicide, so many hectares of farm land can be brought under groundnut production. However, pre-emergence herbicide application alone does not provide season-long weed control in most crops, unless supplemented with post-emergence herbicide or hoe weeding at later stages of growth, according to research (Kraehmer *et al*., 2014; Jabran and Chauhan, 2018). It is therefore crucial to assess how supplementary hoe weeding affects pre-emergence herbicides and certain groundnut varieties in order to determine how well they respond to weed control and how best to maximize yield potential.

MATERIALS AND METHODS

The experiment was conducted during the 2018, 2019 and 2020 wet cropping seasons at Abubakar Tafawa Balewa University Teaching and Research Farm, Gubi, (Lat. 10^{o} 45' N and Long. 9^{o}.82' E, 616m above sea level) situated in the Northern Guinea savanna ecological zone of Nigeria. The experimental site is characterized by a unimodal rainfall pattern which has peak in the month of August. The soil of the experimental site is sandy loam with moderate water holding capacity and pH slightly acidic. The trial consisted of ten (10) weed control treatments which comprised of Butachlor at 2.5 kg a.i.ha^{-1}, Butachlor at 2.5 kg a.i.ha^{-1}, Butachlor at 2.0 +

Pendimethalin 1.0 kg a.i.ha^{-1}, Butachlor at 1.5 kg a.i.ha^{-1} *fb* SHW (Supplementary hoe weeding) at 6 WAS (Weeks after sowing), Butachlor at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS, Pendimethalin at 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS, Pendimethalin at 2.0 kg a.iha^{-1} *fb* SHW at 6 WAS, two hoe weeding at 3 and 6 WAS and weedy check and three varieties of groundnut (SAMNUT 14, SAMNUT 22 & SAMNUT 23). These were laid out in a split plot design and replicated three (3) times. The crop varieties were assigned to the main plots while weed control treatments were assigned to the sub-plots. In each year of the trial, the field was harrowed twice to fine tilth and ridged into 0.75m apart using ox-drown ridger. It was then marked into the required number of plots each of gross area of 3 x 4 m (12 m^2) and net plot size of 1.5 x 3 m (4.5 m^2). The ally between main plots, sub-plots and replicates were 1.0 m, 0.5 m and 1.5 m while nutrients at the rate of 20 kg N, 54 kg P_2O_5 and 20 Kg K_2O was applied basally to each plot using 15:15:15 and 34 kg of P_2O_5 using SSP (18% P_2O_5). Sowing was done on the 28th July 2018, 18th July 2019 and 26th of July 2020 seasons using treated seeds of groundnut obtained from Bauchi State Agricultural Development Programme (BSADP) Ministry of Agriculture, Bauchi State. Three seeds were sown along the ridge per hole at a depth of 2 cm and the resultant seedlings were thinned to one plant per stand at 3 weeks after sowing (WAS). The pre-emergence herbicides were applied as per treatment basis a day after sowing using a Cp3 knapsack sprayer set at a pressure of 2.1kg/m^2. Hoe weeding was carried out at 3 and 6 WAS for the hoe weeded plots. Harvest was done on the 15th, 18th and 26th of November 2018, 2019 and 2020 seasons, respectively. Data were collected on weed characters such weed control index, treatment efficiency index, crop resistance index and weed index; crop attributes such as plant height, number of branches, canopy spread, 100 kernel weight, pod yield, haulm yield and shelling percentage. Data collected were subjected to analysis of variance using Genstat (17th Edition) where the 'F' test shows significance. The treatment means were separated using Duncan's multiple range test (Duncan, 1955).

Weed control index (WCI) (%)

This was calculated on dry weight basis as described by Misra and Tosh (1979) using the equation below.

$$\text{WCI} = \frac{WDMc - WDMt}{WDMc} x\ 100$$

Where, WDMc = the weed dry weight (unit/m^2) in control plot;
WDMt = the weed dry weight (unit/m^2) in treated plot**.**

Treatment (Herbicide) efficiency index (TEI)

This is the weed killing potential of herbicide treatment and its phytotoxicity on the crop. It was thus determined as described by Rana and Kumar (2014) follows:

$$\text{TEI (\%)} = \frac{\frac{\text{Yield of treatment - Yield of control}}{\text{Yield of control}} \times 100}{\text{Weed weight in treatment} \times 100}$$

Weed weight in control

Crop resistance index (CRI)

This indicated the relationship between a proportionate increase in crop biomass in treated plots and a proportionate reduction in weed biomass in the treated plots. Thus, it was determined as described by Rana and Kumar (2014) as follows:

$$CRI = \frac{\text{Crop weight in treated plot}}{\text{Crop weight in control plot}} \; X \; \frac{\text{Weed weight in control plot}}{\text{Weed weight in treated plot}}$$

Weed index (%)

This is the percentage yield loss caused due to weeds as compared to weed free check. Higher weed index indicates greater loss. Hence, weed index (WI) was calculated using the formula described by Rana and Kumar (2014).

$$W.I = \frac{Yield\ from\ weed\ free\ check - Yield\ from\ treated\ plot}{Yield\ from\ the\ weed\ free\ check} \times 100$$

RESULTS

Effect of weed control, variety and season on weeds

Weed control index, treatment efficiency index, crop resistance index and weed index.

The mean of combined analysis on the effect of weed control and variety on weed control index, treatment efficiency index, crop resistance index and weed index of groundnut is shown in Table 1. Result shows that weed control index (WCI) and treatment efficiency index (TEI) were significantly ($P \leq 0.01$) influenced by weed control, variety, season and interaction. Application of hoe weeded twice at 3 and 6 WAS and pendimethalin at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS significantly ($P \leq 0.01$) resulted in higher WCI compared with butachlor at 2.5 kg a.i.ha^{-1} alone

Table 1: Mean of combined analysis across seasons on the influence of supplementary hoe weeding on efficacy of pre-emergence herbicides on weed control index, treatment efficiency index, crop resistance index and weed index of groundnut during 2018, 2019 and 2020 rainy seasons

Treatment	Rate (Kg a.i.ha^{-1})	Weed control index (%)	Treatment efficiency index (TEI)	Crop resistance index (CRI)	Weed index (%)
Weed control (W)					
BUTA	2.5	49.20^{f}	6.70^{h}	2.16^{i}	53.28^{b}
PENDA	2.5	52.95^{e}	7.66^{g}	2.61^{h}	46.38^{c}
BUTA + PENDA	2.0 + 1.0	56.64^{d}	9.37^{f}	3.24^{g}	38.70^{d}
PEND + BUTA	2.0 + 1.0	58.42^{d}	10.73^{e}	4.31^{f}	31.77^{e}
BUTA fb[1] SHW[2] at 6 WAS[3]	1.5	82.25^{c}	18.84^{d}	11.02^{e}	12.34^{f}
BUTA fb SHW at 6 WAS	2.0	85.81^{b}	21.24^{c}	12.70^{d}	8.38^{g}
PEND fb SHW at 6 WAS	1.5	86.20^{b}	23.13^{b}	14.42^{c}	4.99^{h}
PEND fb SHW at 6 WAS	2.0	88.76^{a}	24.60^{a}	15.11^{ab}	3.06^{i}
Weeding at 3 and 6 WAS	-	88.93^{a}	25.15^{a}	15.39^{a}	2.99^{i}

Weedy check	-	-	-	0.10[j]	91.90[a]
Level of significance		**	**	**	**
SE (±)		0.659	0.210	0.056	0.66
Variety (V)					
SAMNUT 22		73.97[a]	16.86	8.61[a]	28.67
SAMNUT 23		71.90[b]	16.46	8.33[b]	28.98
SAMNUT 14		69.62[c]	16.08	7.34[c]	29.73
Level of significance		**	NS	**	NS
SE (±)		0.439	0.52	0.084	0.45
Season (Y)					
2018		70.65[b]	12.16[b]	7.80	28.34
2019		73.42[a]	24.82[a]	8.26	30.70
2020		72.84[a]	24.38[a]	8.24	29.15
Level of significance		*	**	NS	NS
SE (±)		0.681	0.47	0.150	0.90
Interaction					
W x V		**	NS	**	**
W x Y		NS	**	**	NS
V x Y		NS	NS	NS	NS
W x V x Y		NS	NS	NS	NS

Means followed by the same letter (s) within a column are not significantly different at 5% level of probability using Duncan Multiple Range Test. BUTA =Butachlor; PENDA = Pendimethalin. fb[1]= Followed by; SHW= Supplementary hoe weeding; WAS= Weeks after sowing. ** = significant at 1% (P ≤ 0.01); * = significant at 5% (P ≤ 0.05); NS = Not significant.

that resulted in lower WCI. SAMNUT 22 variety significantly (P ≤ 0.01) had higher WCI compared with other varieties. Growing groundnut in 2019 and 2020 seasons significantly resulted in higher WCI and TEI than 2018 season. Interaction effect between weed control and variety on WCI of groundnut was significant (Table 2). Results reveals that hoe weeding twice at 3 and 6 WAS in SAMNUT 22 significantly (P ≤ 0.01) resulted in higher WCI though statistically comparable with two hoe weeding's at 3 and 6 WAS in SAMNUT 23 and SAMNUT 14, pendimethalin at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS, pendimethalin at 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS, butachlor at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS and butachlor at 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS in SAMNUT 22, SAMNUT 23 and SAMNUT 14 compared with the rest of the interaction effects.

Table 2: Interaction effect between weed control and variety on weed control index of groundnut in 2018, 2019 and 2020 (combined season)

Weed control	Rate (Kg a.i.ha^{-1})	Variety		
		SAMNUT 22	SAMNUT 23	SAMNUT 14
BUTA	2.5	39.32^{hi}	38.94^{i}	38.24^{i}
PENDA	2.5	43.91^{fg}	42.27^{gh}	39.33^{hi}
BUTA + PENDA	2.0 + 1.0	47.14^{ef}	46.58^{ef}	46.20^{ef}
PEND + BUTA	2.0 + 1.0	48.56^{e}	48.41^{e}	48.29^{e}
BUTA fb^{1} SHW^{2} at 6 WAS^{3}	1.5	85.72^{bc}	85.57^{c}	75.47^{d}
BUTA fb SHW at 6 WAS	2.0	87.16^{abc}	87.13^{abc}	87.03^{abc}
PEND fb SHW at 6 WAS	1.5	88.32^{abc}	88.22^{abc}	88.04^{abc}
PEND fb SHW at 6 WAS	2.0	89.02^{a}	88.48^{abc}	88.77^{ab}
Weeding at 3 and 6 WAS	-	89.19^{a}	88.82^{ab}	88.79^{ab}
Weedy check	-	-	-	-
Level of significance			**	
SE (±)			1.163	

Means followed by the same letter (s) within a column are not significantly different at 5% level of probability using Duncan Multiple Range Test. BUTA =Butachlor; PENDA = Pendimethalin.fb^{1}= Followed by; SHW= Supplementary hoe weeding; WAS= Weeks after sowing.

** = significant at 1% (P ≤ 0.01); NS = Not significant.

Table 3 presents the interaction effect between weed control and season on TEI. Results indicates that application of hoe weeding twice at 3 and 6 WAS and pendimethalin at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS in 2019 season significantly (P ≤ 0.01) resulted in higher TEI compared with the remaining interaction effects.

Table 3: Interaction effect between weed control and season on treatment efficiency index of groundnut in 2018, 2019 and 2020 seasons at Gubi

Weed control	Rate (Kg a.i.ha^{-1})	Season		
		2018	2019	2020
BUTA	2.5	2.91^{w}	14.16^{q}	12.97^{rs}
PENDA	2.5	3.82^{v}	15.24^{q}	13.87^{qr}
BUTA + PENDA	2.0 + 1.0	5.60^{tu}	16.82^{op}	15.64^{pq}
PEND + BUTA	2.0 + 1.0	6.89^{t}	18.53^{kl}	16.93^{op}
BUTA fb^{1} SHW^{2} at 6 WAS^{3}	1.5	15.06^{nop}	26.27^{g}	25.12^{h}
BUTA fb SHW at 6 WAS	2.0	17.37^{mno}	28.90^{c}	27.41^{ef}
PEND fb SHW at 6 WAS	1.5	18.48^{klm}	32.32^{b}	28.53^{cde}
PEND fb SHW at 6 WAS	2.0	19.21^{ijk}	35.30^{a}	29.26^{cd}
Weeding at 3 and 6 WAS	-	19.63^{i}	36.06^{a}	29.70^{c}
Weedy check	-	-	-	-
Level of significance			**	
SE (±)			0.58	

Means followed by the same letter (s) within a column are not significantly different at 5% level of probability using Duncan Multiple Range Test. BUTA =Butachlor; PENDA = Pendimethalin.fb[1]= Followed by; SHW= Supplementary hoe weeding; WAS= Weeks after sowing.
** = significant at 1% (P ≤ 0.01).

Crop resistance index (CRI) was significantly influenced by weed control, variety and interaction (Table 1). The application of hoe weeding twice at 3 and 6 WAS was highly significant (P ≤ 0.01) with higher CRI compared to other weed control treatments while weedy check resulted significantly in lower CRI. SAMNUT 22 variety significantly (P ≤ 0.01) resulted higher CRI compared to other varieties. The interaction effects between weed control and variety on CRI (Table 4) indicates that two hoe weeding's at 3 and 6 WAS in SAMNUT 22 produced highly significantly (P ≤ 0.01) greater CRI compared to weedy check applied to SAMNUT 22, SAMNUT 23 and SAMNUT 14 that resulted in lower CRI.

Table 4: Interaction effect between weed control and variety on crop resistance index of groundnut in 2018, 2019 and 2020 (combined season)

	Rate	Variety		
Weed control	(Kg a.i.ha^{-1})	SAMNUT 22	SAMNUT 23	SAMNUT 14
BUTA	2.5	2.24^{o}	2.20^{o}	2.04^{o}
PENDA	2.5	2.83^{n}	2.68^{n}	2.31^{o}
BUTA + PENDA	2.0 + 1.0	3.29^{lm}	3.29^{lm}	3.02^{mn}
PEND + BUTA	2.0 + 1.0	4.58^{j}	4.26^{jk}	4.09^{k}
BUTA fb[1] SHW[2] at 6 WAS[3]	1.5	13.58^{f}	11.51^{h}	9.90^{i}
BUTA fb SHW at 6 WAS	2.0	13.62^{ef}	11.59^{h}	9.94i
PEND fb SHW at 6 WAS	1.5	15.27^{d}	15.00^{d}	11.58^{h}
PEND fb SHW at 6 WAS	2.0	16.12^{b}	15.62^{c}	12.98^{g}
Weeding at 3 and 6 WAS	-	16.51^{a}	15.80^{bc}	13.86^{e}
Weedy check	-	0.10^{p}	0.10^{p}	0.10^{p}
Level of significance			**	
SE (±)			0.125	

Means followed by the same letter (s) within a column are not significantly different at 5% level of probability using Duncan Multiple Range Test. BUTA =Butachlor; GLYP = Glyphosate; PENDA = Pendimethalin.fb[1]= Followed by; SHW= Supplementary hoe weeding; WAS= Weeks after sowing.
** = significant at 1% (P ≤ 0.01); NS = Not significant.

On the other hand, interaction between weed control and season (Table 5) reveals that weeding twice at 3 and 6 WAS in 2019 and 2020 was highly significantly (P ≤ 0.01) which resulted in higher CRI though at par with weeding twice at 3 and 6 WAS in 2018, pendimethalin at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS in all the three seasons compared with the rest of the interaction effects while weedy check resulted in lower CRI in all the three seasons.

Result on weed control index (WI) also indicates that weedy check consistently produced higher WI compared to application of hoe weeding twice at 3 and 6 WAS and pendimethalin at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS which significantly resulted in lower W.I (Table

1). The interaction between weed control and variety on WI was significant (Table 6) which shows that weedy check in SAMNUT 22, SAMNUT 23 and SAMNUT 14 significantly ($P \leq 0.01$) resulted in lower weed index compared with the rest of the interaction effect that resulted in higher weed index.

Table 5: Interaction effect between weed control and season on crop resistance index of groundnut in 2018, 2019 and 2020 seasons

Weed control	Rate (Kg a.i.ha^{-1})	Season 2018	2019	2020
BUTA	2.5	2.02^{o}	2.23^{mno}	2.19^{mno}
PENDA	2.5	2.47^{lmn}	2.68^{kl}	2.62^{klm}
BUTA + PENDA	2.0 + 1.0	3.02^{jk}	3.36^{j}	3.32^{j}
PEND + BUTA	2.0 + 1.0	3.99^{i}	4.47^{i}	4.42^{i}
BUTA fb^{1} SHW^{2} at 6 WAS^{3}	1.5	10.58^{h}	11.23^{g}	11.11^{g}
BUTA fb SHW at 6 WAS	2.0	12.06^{f}	13.06^{e}	13.00^{e}
PEND fb SHW at 6 WAS	1.5	13.89^{d}	14.68^{c}	14.62^{c}
PEND fb SHW at 6 WAS	2.0	14.74^{b}	15.29^{ab}	15.24^{ab}
Weeding at 3 and 6 WAS	-	15.12^{abc}	15.52^{a}	15.50^{a}
Weedy check	-	0.10^{p}	0.10^{p}	0.10^{p}
Level of significance			**	
SE (±)			0.176	

Means followed by the same letter (s) within a column are not significantly different at 5% level of probability using Duncan Multiple Range Test. BUTA =Butachlor; PENDA = Pendimethalin.fb^{1}= Followed by; SHW= Supplementary hoe weeding; WAS= Weeks after sowing.

** = significant at 1% ($P \leq 0.01$).

Table 6: Interaction effect between weed control and variety on weed index of groundnut in 2018, 2019 and 2020 seasons

Weed control	Rate (Kg a.i.ha^{-1})	Variety SAMNUT 22	SAMNUT 23	SAMNUT 14
BUTA	2.5	39.84^{f}	48.61^{d}	57.04^{b}
PENDA	2.5	39.84^{f}	48.61^{d}	52.62^{c}
BUTA + PENDA	2.0 + 1.0	38.01^{f}	48.61^{d}	52.62^{c}
PEND + BUTA	2.0 + 1.0	32.28^{g}	31.98^{g}	31.07^{g}
BUTA fb^{1} SHW^{2} at 6 WAS^{3}	1.5	12.03^{h}	12.18^{h}	12.81^{h}
BUTA fb SHW at 6 WAS	2.0	7.60^{ij}	7.61^{ij}	9.93^{hi}
PEND fb SHW at 6 WAS	1.5	4.13^{k}	4.88^{jk}	5.96^{jk}
PEND fb SHW at 6 WAS	2.0	2.92^{kl}	3.07^{kl}	3.19^{kl}
Weeding at 3 and 6 WAS	-	2.21^{l}	2.46^{l}	2.82^{l}
Weedy check	-	91.23^{a}	92.37^{a}	92.37^{a}
Level of significance			**	
SE (±)			1.17	

The mean of combined analysis on the effect of weed control and variety on plant height, number of branches plant^{-1}, canopy spread, number of pod plant^{-1}, 100 kernel weight, pod yield, haulm yield and shelling percentage of groundnut is shown in Table 7. Results on plant height showed that weeding twice at 3 and 6 WAS was highly significant ($P \leq 0.01$) producing taller plants though at par with application of pendimethalin at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS, pendimethalin at 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS, butachlor at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS and butachlor at 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS compared to weedy check that produced shorter plants. SAMNUT 22 and SAMNUT 23 varieties significantly ($P \leq 0.01$) produced taller plants than SAMNUT 14 during the sampling period. Plant height did not differ significantly ($P \geq 0.05$) due to season. The interaction between weed control and variety on plant height was significant (Table 8) where result reveals that hoe weeding twice at 3 and 6 WAS in SAMNUT 22 and SAMNUT 23 significantly ($P \leq 0.01$) produced taller plant than the rest of the interaction effects. However, weedy check in SAMNUT 22, SAMNUT 23 and SAMNUT 14 consistently resulted in shorter plants. On the other hand, interaction between variety and season (Table 9) indicates that SAMNUT 22 and SAMNUT 23 in 2019 and 2020 seasons significantly ($P \leq 0.01$) produced taller plants than the rest of the interaction effects.

Result on number of branches plant^{-1} showed that hoe weeded at 3 and 6 WAS, pendimethalin at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS and pendimethalin at 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS though at par produced significantly ($P \leq 0.01$) higher number of branches plant^{-1} compared with the remaining treatments. Weedy check on the other hand, significantly produced the lowest number of branches plant^{-1}. SAMNUT 22 and SAMNUT 23 varieties significantly ($P \leq 0.01$) resulted in higher number of branches plant^{-1} compared with SAMNUT 14 that had lower number of branches across the sampling periods. Cultivation of groundnut in 2019 and 2020 seasons was highly significant ($P \leq 0.01$) and resulted in producing higher number of branches plant^{-1} compared with 2018 season. The interaction between weed control and variety on number of branches plant^{-1} is shown in Table 10, where weeding twice at 3 and 6 WAS, pendimethalin at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS and pendimethalin at 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS in SAMNUT 23 and SAMNUT 22 significantly ($P \leq 0.01$) produced higher number of branches plant^{-1} though at par with pendimethalin at 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS in SAMUNT 22 compared with the rest of the interaction effects. On the other hand, interaction between weed control and season (Table 11) shows that growing groundnut in 2019 season under hoe weeding at 3 and 6 WAS significantly ($P \leq 0.01$) resulted in higher number of branches plant^{-1} which was also at par with the rest of the interaction effects. Similarly, interaction between variety and season on number of branches plant^{-1} is shown in Table 12, where SAMNUT 22 and SAMNUT 23 varieties in 2019 and 2020 seasons significantly ($P \leq 0.01$) produced higher number of branches plant^{-1} than the rest of the interaction effects.

Results on canopy spread indicated that weeding twice at 3 and 6 WAS and pendimethalin at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS significantly ($P \leq 0.01$) resulted in higher canopy spread compared with other treatments. However, weedy check significantly resulted in

producing lower canopy spread plant^{-1}. SAMNUT 22 and SAMNUT 23 varieties significantly ($P \leq 0.01$) produced higher canopy compared with SAMNUT 14 which had lower canopy. On the other hand, growing groundnut in 2019 and 2020 seasons significantly resulted in higher canopy spread plant^{-1} than in 2018 season. Interaction between weed control and variety on canopy spread of groundnut was significant (Table 13) where results indicates that application of hoe weeding twice at 3 and 6 WAS in SAMNUT 22 significantly ($P \leq 0.01$) resulted in higher canopy though statistically comparable with the rest of the interaction effects compared to weedy check in SAMNUT 14 that produced lower canopy plant^{-1}. On the other hand, the interaction between weed control and season on canopy spread plant^{-1} at 12 WAS (Table 14) shows that application of two hoe weeding's at 3 and 6 WAS, pendimethalin at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS, pendimethalin at 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS, butachlor at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS and butachlor at 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS in 2019 and 2020 seasons though at par produced significantly ($P \leq 0.01$) higher canopy spread compared with the remaining interaction effects.

Results on number of pods plant^{-1} was highly significantly influenced by weed control, variety, season and interaction. The application of two hoe weeding's at 3 and 6 WAS and pendimethalin at 3.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS resulted in significantly ($P \leq 0.01$) higher number of pods plant^{-1} compared with weedy check that had lower pods plant^{-1}. SAMNUT 22 and SAMNUT 23 varieties significantly ($P \leq 0.01$) produced higher number of pods plant^{-1} compared to SAMNUT 14 that had lower number of pods. Growing groundnut in 2019 and 2020 seasons significantly ($P \leq 0.05$) produced higher number of pods plant^{-1} than 2018 season. Interaction between weed control and variety on number of pods plant^{-1} is shown in Table 15 which reveals that weeding at 3 and 6 WAS in SAMNUT 23 significantly ($P \leq 0.05$) produced higher number of pods plant^{-1} which is comparable with weeding twice at 3 and 6 WAS in SAMNUT 22 and pendimethalin at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS in SAMNUT 22 and SAMNUT 23 compared with the rest of the interaction effects. The interaction between weed control and season on number of pods plant^{-1} indicates that hoe weeded twice at 3 and 6 WAS and pendimethalin at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS in 2019 and 2020 seasons resulted significantly ($P \leq 0.05$) higher pods number plant^{-1} compared with the remaining interaction effects (Table 16). On the other hand, interaction between variety and season on number of pods plant^{-1} (Table 17) reveals that SAMNUT 22 and SAMNUT 23 varieties in 2019 and 2020 seasons produced significantly ($P \leq 0.05$) higher number of pods plant than the rest of the interactions.

Result of 100 seed weight was significantly influenced by weed control, variety, season and interaction. Application of weeding twice at 3 and 6 WAS and pendimethalin at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS significantly ($P \leq 0.01$) produced higher 100 seed weight which was at par with pendimethalin at 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS, butachlor at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS and butachlor at 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS compared to weedy check that had lower seed weight. The SAMNUT 23 variety was highly significant ($P \leq 0.01$) and resulted in heavier 100

seed weight compared with other varieties. Growing of groundnut in 2019 and 2020 seasons significantly had higher 100 seed weight compared to 2018 season. The interaction between weed control and variety on 100 seed weight (Table 18) indicates the superiority of hoe weeding at 3 and 6 WAS in significantly ($P \leq 0.01$) producing heavier 100 seed weight though at par with other interaction effects.

Table 7: Mean of combined analysis across seasons on the influence of supplementary hoe weeding on efficacy of pre-emergence herbicides on plant height, canopy spread plant^{-1}, number of branches plant^{-1}, number of pods plant^{-1}, 100 kernel weight, kernel yield, haulm yield and shelling percentage of groundnut during 2018, 2019 and 2020 rainy season

Treatment	Rate (Kg a.i.ha^{-1})	Plant height (cm)	Number of branches plant^{-1}	Canopy spread plant^{-1} (cm)	Number of pods plant^{-1}	100 kernel weight (g)	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Shelling percentage (%)
Weed control (W)									
BUTA	2.5	50.77^{f}	12.41^{f}	42.60^{f}	22.81^{f}	29.58^{d}	734.5^{g}	1974de	48.59^{e}
PENDA	2.5	52.07^{e}	14.15^{e}	43.99^{e}	25.41^{e}	30.01^{cd}	771.9^{f}	2059^{cde}	48.59^{e}
BUTA + PENDA	2.0 + 1.0	52.12^{e}	14.33^{e}	46.93^{d}	26.81^{d}	30.14^{cd}	836.7^{e}	2126^{cde}	48.70^{e}
PEND + BUTA	2.0 + 1.0	53.25^{d}	15.78^{d}	46.93^{d}	27.19^{d}	30.84^{c}	894.0^{d}	2248^{bcd}	48.81^{e}
BUTA fb[1] SHW[2] at 6 WAS[3]	1.5	55.33^{c}	17.37^{c}	51.14^{c}	28.67^{c}	35.71^{ab}	1073.7^{c}	2321^{a-d}	59.11^{cd}
BUTA fb SHW at 6 WAS	2.0	56.11^{bc}	17.74^{c}	51.60^{c}	30.22^{b}	35.92^{ab}	1118.7^{b}	2396^{abc}	59.85^{bc}
PEND fb SHW at 6 WAS	1.5	56.74^{b}	18.85^{b}	52.23^{b}	30.63^{b}	36.14^{ab}	1160.4^{a}	2597^{ab}	60.52^{ab}
PEND fb SHW at 6 WAS	2.0	58.94^{ab}	19.48^{ab}	53.25^{a}	34.11^{a}	37.10^{a}	1167.9^{a}	2649^{ab}	60.78^{a}
Weeding at 3 and 6 WAS	-	60.42^{a}	20.04^{a}	53.27^{a}	34.85^{a}	37.43^{a}	1173.6^{a}	2709^{a}	61.15^{a}
Weedy check	-	45.03^{g}	11.14^{g}	34.28^{g}	13.37^{g}	19.82^{e}	465.6^{h}	1431^{f}	40.37^{f}
Level of significance		**	**	**	**	**	**	**	**
SE (±)		0.357	0.285	0.217	0.347	0.652	12.11	131.3	0.2794
Variety (V)									
SAMNUT 22		57.20^{a}	18.30^{a}	50.13^{a}	29.98^{a}	30.81^{b}	941.5^{b}	2660^{a}	58.82^{b}
SAMNUT 23		57.68^{a}	18.80^{a}	50.28^{a}	30.83^{a}	34.71^{a}	986.8^{a}	2374^{b}	61.08^{a}
SAMNUT 14		45.63^{b}	11.47^{b}	43.96^{b}	22.61^{b}	32.18^{b}	920.8^{b}	1839^{c}	51.82^{c}
Level of significance		**	**	**	**	**	**	**	**
SE (±)		0.771	0.440	0.423	0.504	0.535	12.85	76.9	0.619
Season (Y)									
2018		52.20	11.47^{b}	30.43^{b}	23.51^{b}	26.77^{b}	787.1^{b}	1704^{c}	56.82^{b}
2019		54.11	18.80^{a}	56.97^{a}	28.96^{a}	37.97^{a}	1031.0^{a}	2685^{a}	60.63^{a}
2020		53.87	18.30^{a}	56.55^{a}	27.98^{a}	35.78^{a}	1011.0^{a}	2504^{b}	59.71^{a}
Level of significance		NS	**	**	*	**	**	**	*
SE (±)		0.767	0.496	0.769	1.136	0.684	32.88	75.1	0.965
Interaction									
W x V		**	**	**	**	**	NS	NS	**
W x Y		NS	**	**	**	NS	NS	**	**
V x Y		*	**	NS	**	NS	NS	NS	NS
W x V x Y		NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within a column are not significantly different at 5% level of probability using Duncan Multiple Range Test. BUTA =Butachlor; GLYP = Glyphosate; PENDA = Pendimethalin.fb[1]= Followed by; SHW= Supplementary hoe weeding; WAS= Weeks after sowing. ** = significant at 1% ($P \leq 0.01$); * = significant at 5% ($P \leq 0.05$); NS = Not significant.

Table 8: Interaction effect between Weed control and Variety on plant height of groundnut at 12 WAS in 2018, 2019 and 2020 combined seasons

Weed control	Rate (Kg a.i.ha^{-1})	Variety		
		SAMNUT 22	SAMNUT 23	SAMNUT 14
BUTA	2.5	54.83^{fhi}	53.09^{ijk}	44.59^{n}
PENDA	2.5	55.17^{fhi}	54.79^{g-j}	45.02^{n}
BUTA + PENDA	2.0 + 1.0	55.62^{f-i}	56.16^{fgh}	46.06^{mn}
PEND + BUTA	2.0 + 1.0	56.03^{fgh}	57.63^{def}	47.53^{lm}
BUTA fb^{1} SHW^{2} at 6 WAS^{3}	1.5	57.53^{efg}	59.63^{cde}	47.94^{l}
BUTA fb SHW at 6 WAS	2.0	60.29^{bcd}	59.68^{b-e}	51.91^{k}
PEND fb SHW at 6 WAS	1.5	60.51^{bc}	60.29^{b-e}	52.47^{jk}
PEND fb SHW at 6 WAS	2.0	60.90^{bc}	61.37^{b}	53.31^{ijk}
Weeding at 3 and 6 WAS	-	66.37^{a}	67.57^{a}	54.02^{h-k}
Weedy check	-	42.70^{o}	41.98^{o}	41.86^{o}
Level of significance			**	
SE (±)			0.969	

Means followed by the same letter (s) within a column are not significantly different at 5% level of probability using Duncan Multiple Range Test. BUTA =Butachlor; PENDA = Pendimethalin.fb^{1}= Followed by; SHW= Supplementary hoe weeding; WAS= Weeks after sowing. **= significant at 1% (P ≤ 0.01).

Table 9: Interaction effect between variety and season on plant height of groundnut at 12 WAS in 2018, 2019 and 2020 seasons

Season	Variety		
	SAMNUT 22	SAMNUT 23	SAMNUT 14
2018	55.37^{b}	55.33^{b}	41.13^{d}
2019	57.93^{a}	56.99^{a}	49.42^{c}
2020	56.88^{a}	55.85^{a}	48.73^{c}
Level of significance		*	
SE (±)		1.334	

Means followed by the same letter (s) within a column are not significantly different at 5% level of probability using Duncan Multiple Range Test. BUTA =Butachlor; PENDA = Pendimethalin.fb^{1}= Followed by; SHW= Supplementary hoe weeding; WAS= Weeks after sowing. * = significant at 5% (P ≤ 0.05).

Table 10: Interaction effect between weed control and variety on Number of branches plant^{-1} of groundnut at 12 WAS in 2018, 2019 and 2020 combined seasons

Weed control	Rate (Kg a.i.ha^{-1})	Variety		
		SAMNUT 22	SAMNUT 23	SAMNUT 14
BUTA	2.5	15.33^{hij}	13.89^{j-m}	10.22^{q}
PENDA	2.5	16.56^{fgh}	15.22^{g-k}	10.22^{q}
BUTA + PENDA	2.0 + 1.0	17.00^{fg}	15.67^{ghi}	10.78^{q}
PEND + BUTA	2.0 + 1.0	18.56^{de}	17.22^{ef}	11.56^{pq}
BUTA fb^{1} SHW^{2} at 6 WAS^{3}	1.5	19.78^{cd}	19.78^{cd}	12.44^{m-p}
BUTA fb SHW at 6 WAS	2.0	21.33^{bc}	20.22^{cd}	12.56^{m-p}

PEND fb SHW at 6 WAS	1.5	21.89^{ab}	22.22^{a}	12.67^{m-p}
PEND fb SHW at 6 WAS	2.0	22.11^{a}	22.44^{a}	13.89^{i-n}
Weeding at 3 and 6 WAS	-	22.78^{a}	23.11^{a}	14.22^{i-l}
Weedy check	-	13.67^{k-o}	13.22^{l-p}	8.33^{r}
Level of significance			**	
SE (±)			0.643	

Table 11: Interaction effect between weed control and season on number of branches plant^{-1} of groundnut at 12 WAS in 2018, 2019 and 2020 seasons

	Rate	Season		
Weed control	(Kg a.i.ha^{-1})	2018	2019	2020
BUTA	2.5	12.26^{l}	12.78^{l}	12.67^{l}
PENDA	2.5	14.00^{k}	15.00^{j}	15.00^{j}
BUTA + PENDA	2.0 + 1.0	15.14^{k}	15.22^{j}	15.20^{j}
PEND + BUTA	2.0 + 1.0	16.65^{hi}	17.67^{gh}	17.66^{gh}
BUTA fb[1] SHW[2] at 6 WAS[3]	1.5	19.63^{fgh}	19.67^{fg}	19.65^{fgh}
BUTA fb SHW at 6 WAS	2.0	20.67^{df}	20.67^{ef}	20.65^{df}
PEND fb SHW at 6 WAS	1.5	21.08^{bcd}	22.11^{bcd}	22.10^{bcd}
PEND fb SHW at 6 WAS	2.0	23.15^{abc}	23.22^{abc}	23.21^{abc}
Weeding at 3 and 6 WAS	-	23.68^{ab}	23.78^{a}	23.76^{ab}
Weedy check	-	10.50^{mn}	11.33^{m}	11.31^{m}
Level of significance			**	
SE (±)			0.682	

Means followed by the same letter (s) within a column are not significantly different at 5% level of probability using Duncan Multiple Range Test. BUTA =Butachlor; GLYP = Glyphosate; PENDA = Pendimethalin.fb[1]= Followed by; SHW= Supplementary hoe weeding; WAS= Weeks after sowing.
** = significant at 1% (P ≤ 0.01).

Table 12: Interaction effect between variety and season on number of branches plant^{-1} of groundnut at 12 WAS in 2018, 2019 and 2020 seasons

	Variety		
*Season	SAMNUT 22	SAMNUT 23	SAMNUT 14
2018	13.00^{b}	12.40^{b}	10.02^{d}
2019	22.00^{a}	21.63^{a}	11.73^{c}
2020	22.00^{a}	21.63^{a}	11.63^{c}
Level of significance		**	
SE (±)		0.795	

Means followed by the same letter (s) within a column are not significantly different at 5% level of probability using Duncan Multiple Range Test.
** = significant at 1% (P ≤ 0.01).

Table 13: Interaction effect between weed control and variety on canopy spread plant^{-1} of groundnut at 12 WAS in 2018, 2019 and 2020 (combined season)

Weed control	Rate (Kg a.i.ha^{-1})	Variety		
		SAMNUT 22	SAMNUT 23	SAMNUT 14
BUTA	2.5	44.12^{mn}	45.63^{lm}	38.85^{pq}
PENDA	2.5	45.99^{kl}	47.13^{jk}	40.87^{o}
BUTA + PENDA	2.0 + 1.0	49.06^{hi}	48.51^{hi}	41.44^{o}
PEND + BUTA	2.0 + 1.0	50.85^{g}	48.89^{hi}	42.85^{n}
BUTA fb^{1} SHW^{2} at 6 WAS^{3}	1.5	53.56^{b-f}	52.93^{f}	46.68^{kl}
BUTA fb SHW at 6 WAS	2.0	53.72^{a-f}	53.82^{a-f}	47.51^{ijk}
PEND fb SHW at 6 WAS	1.5	54.51^{a-e}	54.24^{a-f}	47.94^{ij}
PEND fb SHW at 6 WAS	2.0	54.97^{abc}	54.94^{a-d}	49.78^{gh}
Weeding at 3 and 6 WAS	-	55.03^{a}	55.00^{ab}	49.85^{gh}
Weedy check	-	40.28^{op}	38.05^{q}	36.70^{r}
Level of significance			**	
SE (±)			0.553	

Table 14: Interaction effect between weed control and season on canopy spread plant^{-1} of groundnut at 12 WAS in 2018, 2019 and 2020 seasons

Weed control	Rate (Kg a.i.ha^{-1})	Season		
		2018	2019	2020
BUTA	2.5	33.14^{op}	48.67^{jk}	48.65^{ik}
PENDA	2.5	33.23^{op}	50.85^{i}	50.83^{ij}
BUTA + PENDA	2.0 + 1.0	33.31^{o}	55.01^{h}	55.08^{h}
PEND + BUTA	2.0 + 1.0	33.31^{o}	55.14^{h}	55.13^{h}
BUTA fb^{1} SHW^{2} at 6 WAS^{3}	1.5	37.47^{mn}	61.20^{fg}	61.20^{fg}
BUTA fb SHW at 6 WAS	2.0	37.53^{mn}	62.24^{b-g}	62.22^{b-g}
PEND fb SHW at 6 WAS	1.5	37.53^{m}	63.10^{a-e}	63.08^{a-f}
PEND fb SHW at 6 WAS	2.0	37.64^{mn}	64.76^{abc}	64.74^{a-d}
Weeding at 3 and 6 WAS	-	38.01^{m}	64.86^{a}	64.84^{ab}
Weedy check	-	30.14^{q}	43.85^{l}	43.81^{l}
Level of significance			**	
SE (±)			0.848	

Means followed by the same letter (s) within a column are not significantly different at 5% level of probability using Duncan Multiple Range Test. BUTA =Butachlor; PENDA = Pendimethalin.fb^{1}= Followed by; SHW= Supplementary hoe weeding; WAS= Weeks after sowing.

** = significant at 1% (P ≤ 0.01).

Table 15: Interaction effect between weed control and variety on number of pods plant^{-1} of groundnut in 2018, 2019 and 2020 seasons

Weed control	Rate (Kg a.i.ha^{-1})	Variety		
		SAMNUT 22	SAMNUT 23	SAMNUT 14
BUTA	2.5	23.56^{lm}	25.78^{jk}	19.44^{o}
PENDA	2.5	28.44^{fgh}	27.89^{g-j}	19.78^{o}
BUTA + PENDA	2.0 + 1.0	28.56^{efg}	29.33$_{efg}$	22.33^{mn}
PEND + BUTA	2.0 + 1.0	28.78^{fg}	30.11^{ef}	23.00^{lm}
BUTA fb^{1} SHW^{2} at 6 WAS^{3}	1.5	30.56^{de}	32.00^{cd}	23.44^{lm}
BUTA fb SHW at 6 WAS	2.0	32.67^{c}	32.78^{c}	24.67^{kl}
PEND fb SHW at 6 WAS	1.5	33.22^{c}	32.89^{c}	26.33^{hjk}
PEND fb SHW at 6 WAS	2.0	36.67^{b}	37.33^{ab}	27.22^{g-j}
Weeding at 3 and 6 WAS	-	38.44^{ab}	39.00^{a}	28.22^{f-i}
Weedy check	-	20.67^{no}	19.11^{o}	12.00^{p}
Level of significance			**	
SE (±)			0.761	

Means followed by the same letter (s) within a column are not significantly different at 5% level of probability using Duncan Multiple Range Test. BUTA =Butachlor; PENDA = Pendimethalin.fb^{1}= Followed by; SHW= Supplementary hoe weeding; WAS= Weeks after sowing.
** = significant at 1% (P ≤ 0.01).

Table 16: Interaction effect between weed control and season on number of pods plant^{-1} of groundnut in 2018, 2019 and 2020 seasons

Weed control	Rate (Kg a.i.ha^{-1})	Season		
		2018	2019	2020
BUTA	2.5	22.89^{no}	25.15^{h-p}	24.71^{h-p}
PENDA	2.5	22.78^{m-q}	25.56^{g-o}	25.16^{g-n}
BUTA + PENDA	2.0 + 1.0	25.33^{h-p}	27.44^{f-k}	26.72^{e-l}
PEND + BUTA	2.0 + 1.0	25.56^{h-p}	27.78^{fgh}	26.68^{e-i}
BUTA fb^{1} SHW^{2} at 6 WAS^{3}	1.5	26.00^{h-m}	30.33^{cde}	30.13^{c-f}
BUTA fb SHW at 6 WAS	2.0	26.67^{e-m}	32.00^{bcd}	31.82^{bcd}
PEND fb SHW at 6 WAS	1.5	27.44^{e-j}	32.22^{b}	32.01^{bc}
PEND fb SHW at 6 WAS	2.0	27.89^{efg}	37.22^{a}	37.12^{a}
Weeding at 3 and 6 WAS	-	28.33^{b-g}	38.11^{a}	37.97^{a}
Weedy check	-	19.89^{qr}	16.18^{r}	16.11^{r}
Level of significance			**	
SE (±)			1.272	

Table 17: Interaction effect between variety and season on number of pods plant^{-1} of groundnut in 2018, 2019 and 2020 seasons

	Variety		
Season	SAMNUT 22	SAMNUT 23	SAMNUT 14
2018	26.53^{bc}	27.37^{b}	20.40^{e}
2019	31.70^{a}	32.57^{a}	22.63^{d}
2020	30.71^{a}	31.77^{a}	22.60^{d}
Level of significance		**	
SE (±)		1.341	

Table 18: Interaction effect between weed control and variety on 100 seed weight of groundnut in 2018, 2019 and 2020 seasons

	Rate	Variety		
Weed control	(Kg a.i.ha^{-1})	SAMNUT 22	SAMNUT 23	SAMNUT 14
BUTA	2.5	32.40^{f-k}	32.48^{f-k}	30.09^{klm}
PENDA	2.5	32.48^{f-k}	34.14^{e-j}	30.75^{kl}
BUTA + PENDA	2.0 + 1.0	34.31^{e-j}	34.44^{e-i}	31.26^{h-k}
PEND + BUTA	2.0 + 1.0	34.65^{b-g}	34.52^{c-h}	31.98^{g-k}
BUTA fb[1] SHW[2] at 6 WAS[3]	1.5	35.83^{b-e}	36.14^{b-e}	34.49^{c-h}
BUTA fb SHW at 6 WAS	2.0	36.19^{b-e}	36.50^{a-e}	35.36^{b-f}
PEND fb SHW at 6 WAS	1.5	36.69^{a-e}	37.43^{a-e}	35.73^{b-f}
PEND fb SHW at 6 WAS	2.0	37.74^{a-d}	37.97^{ab}	36.14^{b-e}
Weeding at 3 and 6 WAS	-	37.82^{abc}	39.66^{a}	36.52^{a-e}
Weedy check	-	28.05^{m}	27.83^{mn}	25.57^{o}
Level of significance			**	
SE (±)			1.197	

Means followed by the same letter (s) within a column are not significantly different at 5% level of probability using Duncan Multiple Range Test. BUTA =Butachlor; PENDA = Pendimethalin.fb[1]= Followed by; SHW= Supplementary hoe weeding; WAS= Weeks after sowing.

** = significant at 1% ($P \leq 0.01$).

Table 19: Interaction effect between weed control and season on haulm yield of groundnut in 2018, 2019 and 2020 seasons

Weed control	Rate (Kg a.i.ha^{-1})	Season		
		2018	2019	2020
BUTA	2.5	1238^{h}	2127^{ef}	2011^{ef}
PENDA	2.5	1322^{h}	2293de	2217de
BUTA + PENDA	2.0 + 1.0	1337^{h}	2393^{cde}	2326^{cde}
PEND + BUTA	2.0 + 1.0	1393^{gh}	2581^{b-e}	2500^{b-e}
BUTA fb[1] SHW[2] at 6 WAS[3]	1.5	1581^{fgh}	2885^{a-d}	2772^{a-d}
BUTA fb SHW at 6 WAS	2.0	1598^{fgh}	2933^{abc}	2881^{abc}
PEND fb SHW at 6 WAS	1.5	2011^{efg}	3153^{ab}	3160^{ab}
PEND fb SHW at 6 WAS	2.0	2011^{efg}	3204^{ab}	3100^{ab}
Weeding at 3 and 6 WAS	-	2355^{cde}	3265^{a}	3205^{a}
Weedy check	-	1195^{hi}	1538^{fgh}	1457^{fgh}
Level of significance			**	
SE (±)			228.4	

Table 20: Interaction effect between weed control and variety on shelling percentage of groundnut in 2018, 2019 and 2020 seasons

Weed control	Rate (Kg a.i.ha^{-1})	Variety		
		SAMNUT 22	SAMNUT 23	SAMNUT 14
BUTA	2.5	48.22^{ijk}	48.00^{ijk}	47.33^{k-n}
PENDA	2.5	48.22^{ijk}	48.56^{ijk}	47.33^{k-n}
BUTA + PENDA	2.0 + 1.0	48.22^{ijk}	48.89^{ijk}	47.56^{klm}
PEND + BUTA	2.0 + 1.0	48.22^{ijk}	49.33^{ij}	47.56^{klm}
BUTA fb[1] SHW[2] at 6 WAS[3]	1.5	59.33^{e-h}	59.33^{e-h}	58.00^{gh}
BUTA fb SHW at 6 WAS	2.0	60.67^{def}	60.67^{def}	59.33^{f-i}
PEND fb SHW at 6 WAS	1.5	60.78^{cde}	62.00^{cd}	59.67^{efg}
PEND fb SHW at 6 WAS	2.0	62.22^{bc}	62.22^{bc}	60.67^{def}
Weeding at 3 and 6 WAS	-	64.00^{a}	64.00^{a}	63.22^{ab}
Weedy check	-	35.67^{o}	35.67^{o}	35.33^{op}
Level of significance			**	
SE (±)			0.771	

Table 21: Interaction effect between weed control and season on shelling percentage of groundnut in 2018, 2019 and 2020 seasons

Weed control	Rate (Kg a.i.ha^{-1})	Season		
		2018	2019	2020
BUTA	2.5	46.67^{l-s}	57.56^{f-q}	56.61^{f-r}
PENDA	2.5	46.67^{l-s}	57.78^{e-o}	56.83^{e-p}
BUTA + PENDA	2.0 + 1.0	46.89^{k-u}	58.89^{d-m}	56.79^{d-n}
PEND + BUTA	2.0 + 1.0	46.89^{k-u}	58.89^{d-k}	56.92^{b-l}
BUTA fb[1] SHW[2] at 6 WAS[3]	1.5	53.00^{j-t}	60.21^{b-i}	59.18^{b-j}
BUTA fb SHW at 6 WAS	2.0	53.00^{j-t}	61.33^{b-g}	59.57^{b-h}
PEND fb SHW at 6 WAS	1.5	54.89^{g-s}	62.22^{a-e}	61.63^{a-f}
PEND fb SHW at 6 WAS	2.0	55.89^{g-s}	62.33^{abc}	62.10^{abc}
Weeding at 3 and 6 WAS	-	55.89^{g-r}	63.22^{a}	62.88^{a}
Weedy check	-	36.00^{uv}	36.33^{r-v}	36.00^{uv}
Level of significance			**	
SE (±)			1.069	

Means followed by the same letter (s) within a column are not significantly different at 5% level of probability using Duncan Multiple Range Test. BUTA =Butachlor; PENDA = Pendimethalin.fb[1]= Followed by; SHW= Supplementary hoe weeding; WAS= Weeks after sowing.
** = significant at 1% (P ≤ 0.01); NS = Not significant.

DISCUSSIONS

Effect of weed control, variety and season on weed parameters

The significantly higher weed control index obtained by such treatments might be attributed to the treatments' low weed index values as a result of season long weed management. This backs up the findings of Sah *et al*. (2017) and Sahoo *et al*. (2017) who found that pendimethalin and oxyfluorfen supplemented with hoe weeding each, reduced weed density and weed index when compared to sole application for weed control in ginger and groundnut, respectively. The improved vigour of crop plants due to weed control strategies could explain the higher CRI and TEI obtained. The hand weeding at 3 and 6 WAS together with pendimethalin at 2.0 kg a.i. ha^{-1} *fb* SHW at 6 WAS recorded the highest CRI and TEI. The unweeded control, on the other hand, had the lowest CRI, showing that weeds were the most damaging to the crop. Siddhu *et al*. (2018) found similar results in pigeon pean and onions, respectively. Similarly, in rice and soybean, Mishra *et al*. (2016) and Lal *et al*. (2017) observed higher CRI and TEI in herbicidal treated plots followed by SHW at intervals due to season-long weed control, which was statistically comparable to hoe weeding twice. Higher WI obtained in weedy check could be to unrestricted weed growth throughout the season resulting in lower CRI as well as growth and yield penalty. Our findings corroborate those of Prashanth *et al*. (2016) and Chandu *et al*. (2018) who discovered higher weed index in rice due to uncontrol weeds resulting in yield penalty. The ability of SAMNUT 22 variety in producing significantly

higher WCI and CRI could be attributed to the variety's genetic makeup, which develops more branches and a higher canopy, smothering the growth of weeds. Higher WCI, and TEI values in the 2019 and 2020 seasons compared to previous season could be attributed to favorable environmental circumstances that resulted in higher treatment efficacy in reducing the weed population, letting the crop to use the available growth resources for assimilate production. This conclusion supports the findings of Siddhu *et al*. (2018) and Rana and Rana (2018) who separately found that herbicidal treated plots with SHW at intervals had greater WCI and TEI due to the treatments' season-long weed control.

Effect of weed control, variety and season on crop performance

Higher growth and yield attributes such as plant height, number of branches, canopy spread, number of pods, 100 were found to be higher in plots that received weed control treatment. This could be attributed to year-round weed control, which resulted in better weed management during the early stages of crop growth, and later weed growth was checked by hoeing, resulting in low weed density and weed dry weight, allowing the crop to take full advantage of available growth resources for optimum growth and development. Plant growth characteristics increased due to low weed density per square meter of crops, according to Priya et al. (2013) and Ferdous *et al.* (2017). Similar findings have been confirmed by Wadafale *et al*. (2011) on increased number of branches of soybean due to season long weed control. Higher canopy spread obtained could be due to higher number of leaves and greater number of branches resulting from the efficacy of the treatments in smothering the growth of weeds. Our findings are similar to those of Sangeetha *et al*. (2012) and Smita *et al*. (2014), who found that an increase in the number of leaves, larger leaves and number of branches plant^{-1} resulted in a higher canopy spread; which in turn increased dry matter production. It is clear that employing preemergence herbicides + SHW at 6 WAS to control weeds eliminates weed interference and increases podding due to optimal nutrient uptake. This assertion was in line with Adhikary *et al*. (2016) who discovered that a larger number of pods plant^{-1} and mean pod weight collected were associated with improved nutrient accretion due less weed infestation, which translates to increased dry matter and CGR from agricultural plants. The higher pod yield, 100 seed weight, haulm yield and shelling percentage produced demonstrates the treatment's effectiveness in causing less crop-weed competition throughout the crop's growth period, less weed count, and less dry weight of weeds enhanced water and food intake, which might have increased the availability of carbohydrates by speeding up photosynthetic activity, led in cell division, multiplication, and elongation, resulting in an increase in cell size for growth and yield production. This current finding is consistent with those of Bhale *et al*. (2012) and Nikhil Reddy *et al*. (2016), who found that effective weed control strategies increased groundnut pod production. Furthermore, Amaregouda *et al*. (2013) further confirm that effective weed control strategies boost soybean growth and pod yield. Olayinka and Etejere (2015) and Kalhapure (2013) also confirmed an increase in groundnut yield components due to effective weed

management. Similarly, Abouziena *et al*. (2013) and Sinha *et al*. (2018) found an increase in 100 kernel weights of groundnut and transplanted kernel yield of rice in Bangladesh due to effective weed control. However, due to continuous competition for growth resources (space, light, nutrients, etc.) with the crops, weedy check considerably reported the shortest plants, number of branches plant, canopy spread, number of pods plant^{-1}, 100 seed weight, pod yield, haulm yield. Due to the negative effect of weed competition, plant growth aspects as reported by Tyagi et al. (2011) and Ferdous *et al*. (2017) were drastically reduced. The much taller plants, number of branches, canopy spread and number of pods generated by SAMNUT 22 and SAMNUT 23 varieties could be attributed to the genetic make-up to produce taller plants with a broader canopy spread under favorable climatic conditions offered by the 2019 and 2020 cropping season could be attributable to better environmental conditions and nutrient uptake, which allowed for the development of more pods per plant^{-1}, which is directly related pod yield, kernel yield, and 100 seed weight than what was obtained in previous season. The SAMNUT 23 variety's dominance in producing significantly heavier 100 kernel weight, pod yield and shelling percentage could be the explanation for the higher 100 seed weight, which was ascribed to the variety's genetic makeup to produce larger and heavier seed sizes due to larger pods. Our findings corroborate those of Parthipan (2020), who found that crops perform better when weeds are efficiently managed. Similarly, Pereira *et al*. (2015) asserted that the number of pods generated by plant^{-1} favored mean pod weight, pod yield, kernel yield, and 100 kernel weight, and that the number of pods produced was also influenced by a variety of environmental factors and management practices adopted.

Interaction effects of weed attributes

The significant interaction obtained between weed control and variety on WCI and CRI demonstrated the efficacy of pre-emergence treated plots that were supplemented with hoe weeding at 6 WAS across SAMNUT 22, SAMNUT 23 and SAMNUT 14 could be aided by season long weed control which reduces crop-weed rivalry for limited growth resources which simultaneously increasing the ability of the varieties ability to establish additional branches and canopy capable of inhibiting weed growth. This finding corroborates those of Meena *et al*. (2011), who reported higher WCI pigeon pea due to maximum weed management resulting in pod yield gain.The significant interaction obtained between weed control and season on TEI and CRI might be ascribed to decreased weed density and weed index, together with prevalent weather conditions, which improves season-long weed control achieved with supplementary hoe weeding applied to the pre-emergence herbicide at 6 WAS, as well as the second weeding applied to the hoe weed treatment that controls the second flush of weeds. As a result, improves the weed control treatments broad-spectrum efficacy. Omisore *et al*. (2016) and Kashid (2019) reported the lowest weed cover score, weed density, and weed index as a result of pre-emergence herbicide application when paired with one hoe weeding, consequently

enhancing WCI and TEI of cowpea and rice, respectively, in Nigeria and India. The significant interaction discovered between weed control and variety on weed index showed that SAMNUT 14, SAMNUT 22 and SAMNUT 23 in weedy check significantly resulted in producing the highest weed index was aided by uninterrupted crop-weed competition for limited growth resources which decreased the ability of the varieties to develop more branches plant^{-1} and canopy spread capable of suppressing weed growth. Our findings corroborate those of Prashanth *et al*. (2016) and Chandu *et al*. (2018) who discovered higher weed index in rice due to uncontrol weeds resulting in yield penalty.

Interaction effects of crop attributes

The significant interaction discovered between weed control and variety on crop attributes such as plant height, number of branches plant^{-1}, canopy spread, number of pods plant^{-1} and shelling percentage could be attributed to higher weed control index, treatment efficiency index, crop resistance index achieved by the treatments in SAMNUT 22 and SAMNUT 23 varieties that enable the varieties to explore their growth and yield potential compared to plots that weeds were kept unabated and resulted in lower crop attributes. Our findings are in line with the findings of Kanatas *et al*. (2020) who reported that herbicide application and cultivar significantly decreased the density of weeds compared to weedy check treatment. Similarly, significant increase in the growth attributes of groundnut due to season and varietal effect could also be attributed to favorable season enjoyed during 2019 and 2020 that led to release of nutrients due to effective weed control that enables the SAMNUT 22 and 23 to effectively utilized the available nutrients to explore their genetic make-up in producing higher growth and yield attributes of groundnut. This corroborates with the earlier reports of Omisore *et al*. (2016) and Kashid *et al*. (2019).

CONCLUSION AND RECOMMENDATIONS

Findings from the field experiments indicated that weed parameters such as weed control index, treatment efficiency index and crop resistance index were significantly lower under the application of pendimethalin at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS and hoe weeding at 3 and 6 WAS compared to weedy check that resulted in higher value. The plant height, number of branches, canopy spread, number of pods plant^{-1} were significantly higher with the application of hoe weeding at 3 and 6 WAS, pendimethalin at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS, pendimethalin at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS. Similarly, 100 kernel weight, haulm yield and shelling were significantly higher with the application of hoe weeding at 3 and 6 WAS, pendimethalin at 2.0 kg a.i.ha^{-1} *fb* SHW at 6 WAS, pendimethalin at 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS, butachlor at 2.0 and 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS. The SAMNUT 22 and 23 varieties produced taller plants with a greater number of branches, canopy spread and number of pods

plant^{-1}. On the other hand, SAMNUT 23 variety significantly produced higher 100 kernel weight, pod yield and shelling percentage while SAMNUT 22 variety produced higher haulm yield, respectively. From the findings it can be deduced that application of pendimethalin at 2.0 and 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS and butachlor at 2.0 and 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS in place of manual weeding at 3 and 6 WAS with SAMNUT 22 or SAMNUT 23 can be adopted by farmers towards boosting groundnut yield in the study area to avert scarcity of manual labour during peak periods.

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