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Evaluation of Foliar Applied Kaolin on Growth Performance of Soybean [*Glycine Max* (L.) Merrill] Under Irrigation in Sudan Savanna of Nigeria

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Abstract— **An experiment was conducted during the hot of dry season of 2019 in the Sudan savanna of Nigeria to evaluate the effect of foliar applied antitranspirant (Kaolin; aluminosilicate (Al4Si4O10 (OH) 8)) on growth and development of soybean [Glycine max (L.) Merrill] under irrigaation.The Teaching and Research Farm of the Faculty of Agriculture Bayero University, Kano (11°97′ 98.6″ N, 8°42′ 03.7″ E) 475 m elevation and Irrigation Research Station , Kadawa under Institute for Agricultural Research Ahmadu Bello University, Zaria (11°38'.40.3" N 8°25' 53.9" E) 498 m elevation represented the two locations used. The treatments consisted of two varieties of soybean (TGX1835-10E and TGX1955-4F), three growth stages for the application of kaolin (node initiation, flower initiation and pod initiation) and four application rates (0%, 3%, 6% and 9% w/v %). The factors were factorially combined and laid out in a split-split-plot design and replicated three times. Varieties were allocated to main plots, growth stages for the application of kaolin in sub plots and kaolin rates in sub-sub plots. Data collected on growth parameters were subjected to analysis of variance (ANOVA) using Statistix-10 and significant means of treatments were separated using Tukey HSD at 5% level of probability. The result obtained after comparison between two varieties of soybean, three growth stages of foliar applied kaolin and four rates shows that variety, application at growth stage and kaolin rates shows highly significance (P≤ 0.01), significance (P≤ 0.05) and non-significant effects on measured growth parameters on; plant height (cm), number of branches plant-1 and leaf area index plant-1 taken at six, nine and twelve weeks after sowing, grain and fodder yield (kgha-1) at harvest.**

Index Terms— **Dry season, variety, growth stage, kaolin rate and growth.**

I. INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is a member of the family Fabaceae.The crop is grown from seed and development is influenced by soil and climatic variables particularly temperature, moisture and day length(Raemekers, 2011).Soybean is a multipurpose crop and among others uses includes local food, medicine, industrial, income, poultry and livestock feeds.The multiple functional status of crop created a wide gap between demand and supply for the rapidly growing population. Production of the crop at present is majorly during wet season, time period of production with high risk and uncertainty due to climatic variables,incidences of pest and diseases and this lead to poor crop growth and development.Although good crop performance can be obtained in dry season period but, production could beconstrained byhigh transpiration rate.High rate of transpiration in soybean is a stress which receives less attention and has something to do with the growth and development of the crop and is enough to cause adverse effects on growth in Sudan savanna of Nigeria. Although plants though various mechanisms increased resistance to transpiration rate but aiding itartificial could improve crop performance. Reducing crop luxury transpiration is important in improving water productivity (Kang *et al*., 2017). Antitranspirant (kaolin) spray on plant leaves was found to decrease leaf temperature by increasing leaf reflectance and reduce transpiration rate more than photosynthesis in many plant species grown at high solar radiation levels (Nakano and Uehara, 1996).In view of the negative effectof high transpiration rate to crops growth and development which can ultimately affect final yield during dry season there has been much interest in finding ways to reduce luxury water losses through high transpiration. However the use of kaolin as an antitranspirant would only be effective when appropriate and or better variety, at the right growth stage and correct rates are used. Therefore, the need of this research "toevaluate the effect of foliar applied kaolin, identify the best growth stage for the application and optimum kaolin rate on growth and development of irrigated soybean".

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II. MATERIALS AND METHODS

Field experiment was conducted during the hot period of dry season in 2019 in the Sudan savanna of Nigeria to evaluate the effect of foliar applied kaolin on growth and development of soybean [*Glycine max* (L.) Merrill] under irrigation at The Teaching and Research Farm of the Faculty of Agriculture Bayero University, Kano (11°97′ 98.6″ N, 8°42′ 03.7″ E) 475 m elevation and Irrigation Research Station, Kadawa under Institute for Agricultural Research Ahmadu Bello University, Zaria (11° 38'.40.3" N 8°2 5' 53.9" E) 498 m elevation represented the two locations used.

Treatments and Experimental Design

The treatments consisted of two varieties of soybean, three growth stages of foliar applied kaolin (node, flower and pod initiation)and four rates of kaolin. The factors were factorially combined and laid out in a split-split-plot design and replicated three times. Varieties were allocated to main plots, growth stages of foliar applied kaolin in sub plots and kaolin rates in sub-sub plots.

Planting Materials

TGX1835-10E and TGX1955-4Fare known for resistance to pest and diseases, high yielding and good for Sudan savannah zone (Dugje *et al*, 2009). The seeds were inoculated with (*Brady rhizobium Japonicum*) and seeds treatment with fungicides (Captan, Apron Plus at the rate of 1 sachet/8 kg of seeds before planting for protection against soil borne fungal diseases.

Plot Size (m^2)

The field of each of the experimental site was marked out in to total size of $1150.5m^2$. It was divided in to three replications with an alley of 2m between. Replications were transformed in to main, sub and sub-sub plots of 3m by 5m with an alley of 0.75m between each. Main plot, sub-plot and sub-sub plot consisted of 4 ridges of 5m by 0.75m ($15m^2$) and net plot sizes (two inner rows) $4.5m^2$.

Sowing, Seed Rate and Spacing

Sowing was observed manually by hand on four ridges side, 6 seeds per hole and were thinned to 4 plants at 3WAS. Spacing between ridges was $0.75m^2$ and 10cm between stands with depth of about 3 to 4cm. Supplying was donned at 10 days after sowing.

Irrigation

Through surface flooding, irrigation water was conveyed in to basin of research plots. Interval of four days between irrigation was maintained in BUK and seven days in Kadawa due to variation in water table and withdrew at pods maturity.

Kaolin Preparation and Application

Powdered, water soluble kaolin was sieved and diluted in water in to different rates (0%, 3%, 6% and 9% w/v) and applied on leaves surfaces. The rates were obtained through;

1g →1ml =100%

1g→99ml = 1%

For 99ml to liter → (÷ 1000/99 = 0.099ml)

Therefore 1% in 15liter of water →X x 15/0.099 = 1g x 15litre/0.099

X = 1x 15/0.099 =151.5g is 1% in 15liter of water

For 3% 151.5g x 3 =454.5g

For 6% 151.5 x 6= 909g

For 9% 151.5g x 9=1363.5g

According to treatment allocation and rates, fine mist of kaolin solutions were sprayed on top and bottom of leaves surfaces until run-off with hand operated (pressure) sprayer. Treatments were in the morning hours and repeated 3 times at five day intervals as kaolin should be applied before high temperature and must be reapplied to protect new growth (Sharma *et al*., 2015).

Sampling and Data Collection

Only two inner rows were used for sampling, five plants were randomly tagged from which data were collected.

Plant Height (cm)

Using calibrated ruler, plant main stem heights were determined at 6, 9 and 12WAS. Measurement was from ground levels to topmost part of tagged plants and averages were recorded.

Number of Branches Plant^{-1}

It was obtained at 6, 9 and 12WAS through counting from five tagged plants and the calculated average recorded.

Leaf Area Index Plant^{-1}

Leaf area was first obtained and the values were computed in to leaf area plant^{-1} material per unit area of ground. It was obtained at 6, 9 and 12WAS using a formula below as described (Sharma and Mehta, 1991)

$$LAI = \frac{\text{Leaf Area Plant}^{-1}}{\text{Ground Area}}$$

III. Crop Growth Rate (g/m^2/wk)

This is an increase in plant material per unit of time. It was determined through the use of Radford (1967) formula.

$$CGR = \frac{W2-W1}{T2-T1}$$

Data Analysis

The data were subjected to analysis of variance (ANOVA) using Statistix-10.Significant means of treatments were separated using Tukey HSD at 5% level of probability.

Result

IV. Plant Height (cm)

The effect of variety, growth stage of foliar applied kaolin, kaolin rate and their interaction on plant heights (cm) of soybean at BUK and Kadawa during the 2019 dry seasons are presented in (Table 1). The result recorded non-significant effect due to variety differences and kaolin application at growth stage across the sampling periods and seasons except at 9WAS and 12WAS in BUK TGX1835-10E produced taller plants (75.61cm) than TGX1955-4F (71.07cm). At 6WAS, variety, application at growth stage and kaolin rate produced plant with same height across seasons, locations and sampling periods. In BUK, application of 3, 6 and 9% kaolin at 9WAS produced significantly ($P \leq 0.01$) taller plants than the control plants. At 12WAS, application of 3 and 6% produced significantly ($P \leq 0.01$) taller plants than the control plant and those treated with 9% kaolin.

In Kadawa, application of 3% and 6% at 9WAS produced significantly ($P \leq 0.01$) taller plants than those at controlled and those treated with 9% kaolin and 0%. At 12WAS application of 3% and 6% recorded significantly ($P \leq 0.01$) taller plants followed plants treated with 9% kaolin and shortest in control.

Significant ($P \leq 0.01$) interaction between variety, growth stage and kaolin rate was observed at 12WAS. In (Table 2) taller plants were recorded in application at pod initiation from TGX1835-10E at 3% kaolin and shorter plants from TGX1955-4F at control in application at pod initiation in Kadawa.

V. Number Branches Plant^{-1}

The effect of variety,application at growth stage, kaolin rate and their interaction on number of branches plant^{-1} of soybean at BUK and Kadawa during the 2019 dry seasons is presented in Table 1. The result shows that at 6WAS variety, application at different growth stages, kaolin rates had no significant effect on number of branches across the sampling periods, seasons and locations. At 12WAS TGX1955-4F produced significantly plants with highest number of branches plant^{-1} than TGX18355-10E in BUK.At 12WAS, effect of application at growth stage recorded significantly ($P \leq 0.01$) highest number of branches, with application at flower initiation higher than application at node and pod initiations.

In Kadawa 2019, effect of kaolin application at growth stage recorded significantly ($P \leq 0.05$) highest number of branches in application at flower initiation at 9WAS and was statistically similar in number of branches recorded with application at node initiation. Lower number of branches were recorded with application at pod initiation and showed statistical similarity with number of branches with application at node initiation.

At 12WAS application at node and flower initiations were statistically similar and has higher number of branches than application at pod initiation.

In BUK, effect of kaolin rate at 9WAS recorded significantly (P≤ 0.05) highest number of branches at 3% kaolin and were statistically similar with those treated with 6 and 9% kaolin. Lower number of branches were recorded at control and indicated statistical similarities with plants treated with 6% and 9% kaolin. At 12WAS, significantly (P≤ 0.05) higher number of branches were recorded with 3% and 6% kaolin and lower at 9% and the control. Result showssignificant interaction of variety and application of kaolin at growth stage at 12WAS.In Kadawa, effect of kaolin rate at 9WAS produced significantly (P≤ 0.01) higher number of branches with application of 3% and 6% kaolin than those treated with 9% and control. At 12WAS, more number of branches were recorded significantly (P≤ 0.05) in application of 6% kaolin and statistically similar with plant treated with 3% kaolin. Lower number of branches with application of 9% kaolin shows statistical similarities in number of branches at 3% and the control. Similarly lowest number of branches at control indicated statistical similarity in plant treated with 9% kaolin. Result showed that there were interaction at 12WAS.In BUK, (Table 3) recorded significant (P≤ 0.01) interaction between variety and growth stage of foliar applied kaolin at 12WAS. Significantly highest number of branches at 12WAS was observed in combination of TGX1955-4F and application at flower initiation while the lowest was observed in TGX1835-10E at pod and node initiation. Lower number of branches in TGX1955-4F in application at node initiation was statistically similar in number of branches in application at flower and pod initiation in TGX1835-10E and TGX1955-4F respectively. Although application at node and pod initiation recorded lowest number of branches in TGX1835-10E but statistically indicated similar number of branches in application at flower and pod initiation in TGX1835-10E and TGX1955-4F respectively.In Kadawa at 12WAS, interaction effect between application at growth stage and kaolin rates in (Table 4) recorded significantly (P≤ 0.05) higher number of branches in application of 6% at node initiation and lowest in application of 3% at pod initiation.

Table 1: Plant Height (cm)and Number of Branches Plant $^{-1}$of Soybean as Affected by Variety, Growth Stage of Foliar Applied Kaolin, and itsRate at BUK and Kadawa during the 2019 Dry Season.

Treatment	BUK (PLH) 2019			Kadawa (PLH) 2019			BUK(NB) 2019			Kadawa(NB) 2019		
	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS
Variety (V)												
TGX1835-10E	18.21	45.32	63.88a	24.73	42.41	75.61a	0.49	2.75	4.61b	0.64	3.14b	5.11b
TGX1955-4F	18.66	42.38	72.06b	22.22	40.65	71.07b	0.53	3.65	6.28a	0.51	4.16a	6.83a
P-Value	0.503	0.476	0.023	0.142	0.241	0.015	0.736	0.132	0.002	0.956	0.043	0.003
SE (±)	0.546	3.367	1.797	1.062	1.065	0.563	0.115	0.36	0.067	0.180	0.311	0.095
Growth Stage (GS)												
Node Initiation	18.06	44.89	69.18	22.87	42.16	72.23	0.51	2.84	5.12b	0.69	3.54ab	6.39a
Flower Initiation	18.74	42.87	69.15	24.10	41.34	73.99	0.58	3.49	6.48a	0.68	4.12a	6.59a
Pod Initiation	18.50	43.78	65.58	23.45	41.10	73.80	0.45	3.27	4.73b	0.56	3.29b	4.94b
P-Value	0.545	0.708	0.723	0.799	0.610	0.530	0.736	0.318	0.001	0.198	0.022	0.001
SE (±)	0.607	2.387	5.969	1.817	1.087	1.643	0.111	0.406	0.210	0.075	0.236	0.180
Kaolin Rate (R)												
0%	18.37	39.42b	60.98b	23.99	36.99b	60.84c	0.52	2.81b	4.31b	0.68	3.44b	4.88c
3%	19.09	45.12a	74.32a	23.10	43.89a	79.32a	0.51	3.66a	5.97a	0.74	3.83a	6.33ab
6%	18.04	47.17a	73.99a	23.19	45.42a	83.96a	0.56	2.44ab	6.90a	0.61	3.87a	7.18a
9%	18.24	43.69a	62.71b	23.59	39.82b	69.43b	0.46	2.89ab	4.84b	0.54	3.45b	5.49bc
P-Value	0.256	0.001	0.004	0.885	0.001	0.001	0.703	0.020	0.003	0.451	0.013	0.001
SE (±)	0.547	1.331	3.607	1.246	1.344	2.687	0.085	0.30	0.268	0.128	0.165	0.399
Interaction												
V* GS	0.940	0.374	0.932	0.928	0.277	0.405	0.253	0.331	0.003	0.078	0.076	0.076
V*R	0.789	0.869	0.520	0.823	0.715	0.176	0.326	0.399	0.079	0.348	0.099	0.615
GS*R	0.602	0.161	0.927	0.731	0.697	0.619	0.514	0.471	0.923	0.473	0.546	0.058
V* GS*R	0.276	0.165	0.632	0.656	0.993	0.016	0.115	0.761	0.325	0.447	0.383	0.809

Means along the same column with unlike letter (s) are statistically different at 5% level of probability.

Table 2: Interaction between Variety, Growth Stage of Foliar Applied Kaolin and Kaolin Rate on Plant Height (cm) of Soybean at 12WAS at Kadawa Dry Season.

Kadawa		**Rate 12WAS**			
		0%	3%	6%	9%
Variety					
TGX1835-10E	NODIN	65.73g-j	72.87c-h	82.53bcd	71.53c-i
	FLWIN	62.07g-j	84.13abc	87.30ab	73.53c-g
	PODIN	59.27ij	96.50a	80.20b-f	71.67c-i
TGX1955-4F	NODIN	60.53hij	81.23b-e	84.13abc	59.30ij
	FLWIN	61.13g-j	72.03c-h	82.43b-e	69.27e-i
	PODIN	56.33j	68.00f-j	87.17ab	71.27d-i
SE (±)	6.5807				

Means with unlike letter (s) are statistically different at 5% level of probability. NODIN= node initiation, FLOIN = flower initiation and PODIN= pod initiation.

Table 3: Interaction between Variety and Growth Stage on Number of Branches Plant^{-1} of Soybean at12WAS at BUK Dry Season.

BUK	**Growth Stage 12WAS**		
	NODIN	FLOIN	PODIN
Variety			
TGX1835-10E	4.49c	5.10bc	4.45c
TGX1955-4F	6.97b	7.85a	5.01bc
SE (±)	0.298		

Means with unlike letter (s) are different at 5% level of probability. NODIN= node initiation, FLOIN = flower initiation and PODIN= pod initiation.

Table 4: Interaction between Growth Stage of Foliar Applied Kaolin and Kaolin Rate on Number of Branches Plant^{-1} of Soybean at12WAS at KadawaDry Season.

	Rate 12WAS			
	0%	3%	6%	9%
Growth Stage				
NODIN	5.05cde	6.05a-e	8.42a	6.03a-e
FLOIN	5.00cde	7.15abc	7.77ab	6.45a-d
PODIN	4.60de	5.78b-e	5.37cde	3.99e
SE (±)		0.692		

Means unlike letter (s) are different at 5% level of probability. NODIN= node initiation, FLOIN = flower initiation and PODIN= pod initiation.

Leaf Area Index Plant^{-1}

The effect of variety, growth stage of foliar applied kaolin, kaolin rate and their interaction on leaf area index plant^{-1}of soybean at BUK and Kadawa during the dry season is presented in (Table 5). The result shows that variety statistically produced plants with same leaf area index plant^{-1} across the sampling periods and locations except at 12WAS in BUK and Kadawa and significantly (P≤ 0.01) TGX19555-4F was higher than TGX1835-10E in leaf area index plant^{-1}.However, kaolin application at growth stage showed non-significant effect at 6WAS across the sampling periods and locations In BUK , application of kaolin at flower and pod initiation recorded significant (P≤ 0.01) wider leaf area index plant^{-1} than application at 9WAS.

Effect of kaolin rate at BUK produced significantly (P≤ 0.01) wider leaf area index with application of 6% and was statistically similar in leaf area index in application of 3% and 9% kaolin at 9WAS. The lower leaf area index at control in 9WAS was statistically similar in leaf area index with application of 3% and 9% kaolin. However at 12WAS application of 6% produced significantly (P≤ 0.01) higher leaf area index and was statistically similar to plants treated with 3% kaolin. The lower leaf area index in plants treated with 9% kaolin was statistically similar in plants treated with 3% kaolin and the lowest was from the control. No significant interaction recorded across the location.

In Kadawa 2019, although they are statistically similar, application of 6% kaolin at 9WAS produced significantly (P≤ 0.01) higher leaf area index than 3% kaolin. Lower leaf area index with application of 9% kaolin was similar with those treated with 3% kaolin and lowest from the control was also similar with 9% treated plants. However, application of 3% kaolin at 12WAS produced significantly (P≤ 0.01) higher leaf area index than 6% kaolin. Lower leaf area index at control and application of 9% kaolin was similar with those treated with 6% kaolin.

VI. Crop Growth Rate (g/m^2/wk)

The influence of variety, growth stage of kaolin application, kaolin rate and their interaction on crop growth rate at BUK and Kadawa during the 2019 dry season are presented in Table 5. The result indicated that variety shows no significant effect on crop growth rate across the sampling periods and locations. The effect of kaolin application at growth stage shows no significant effect on growth rate across the sampling periods and locations except at 9WAS in BUK and 12WAS in Kadawa. Kaolin application at flower and pod initiation recorded significantly (P≤ 0.01) higher crop growth rate at 9WAS in BUK slower growth rate in application at node initiation.

The kaolin rates at 6 and 12WAS in BUKrecorded significantly (P≤ 0.01) higher crop growth rate with application of 3% and 6 % kaolin and statistically indicated similarity in application of 9% kaolin. Slow crop growth rate at control indicated similarity in growth rate in application of 9% kaolin. Significant interaction was recorded at 9WAS. The effect of kaolin rate on growth rate at Kadawa indicated significant (P≤ 0.01) effect at 12WAS. Application of 3, 6 and 9% kaolin at par indicated higher growth rate than the control. In 2020, application of 6% kaolin indicated significantly (P≤ 0.01) higher crop growth rate followed by 3% and slower at 9% and the control. Significant interaction was recorded at 12WAS trial.

Table 6, recorded interaction between variety and crop growth rate at 9WAS in BUK. Higher crop growth rate was recorded significantly (P≤ 0.01) in application at flower initiation in TGX1955-4F and at pod initiation across varieties. Slower crop growth rate in TGX1955- 4F in application at node initiation was statistically similar in growth rate in TGX1955-4F in application at node and flower initiations.

Table 6 shows significant interaction in Kadawaat 12WAS on crop growth rate. The interaction between variety and application at growth stage recorded significantly (P≤ 0.01) higher crop growth rate in kaolin application at pod initiation in TGX1835-10E and was statistically similar with crop growth rate across the growth stages and varieties except TGX1835-10E with application at node initiation which shows slower growth rate.

Table 5: Leaf Area Index Plant^{-1}and Crop Growth Rate of Soybean as Affected by Variety, Growth Stage of Foliar Applied Kaolin and its Rate at BUK and Kadawa during the 2019 Dry Season.

	BUK(LAI)			Kadawa (LAI)			BUK(CGR)			Kadawa(CGR)		
Treatment	2019			2019			2019			2020		
	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS
Variety (V)												
TGX1835-10E	0.38	0.42	0.51	0.36	0.42	0.47b	1.73	5.17	18.03	2.31a	7.13	16.78
TGX1955-4F	0.35	0.44	0.56	0.34	0.44	0.52a	1.97	5.33	16.83	2.17b	5.56	15.72
P-Value	0.098	0.252	0.151	0.123	0.277	0.033	0.428	0.519	0.574	0.017	0.132	0.451
SE (±)	0.030	0.012	0.017	0.016	0.016	0.016	0.239	0.205	1.811	0.040	0.631	2.611
Growth Stage (GS)												
Node Initiation	0.35	0.40	0.48b	0.35	0.42	0.46	1.754	4.34b	15.16	2.07	6.00	17.38
Flower Initiation	0.38	0.44	0.56a	0.35	0.42	0.52	1.80	5.29a	17.62	2.35	6.35	14.79
Pod Initiation	0.36	0.43	0.57a	0.34	0.44	0.50	1.99	6.13a	19.52	2.30	6.68	16.58
P-Value	0.660	0.119	0.005	0.717	0.245	0.069	0.171	0.002	0.080	0.363	0.552	0.649
SE (±)	0.016	0.016	0.022	0.110	0.029	0.021	0.120	0.31	1.651	0.233	0.598	1.783
Kaolin Rate (R)												
0%	0.37	0.40b	0.47c	0.34	0.40c	0.47b	1.67b	4.84	14.48b	2.20	5.745	12.83c
3%	0.37	0.43ab	0.56ab	0.34	0.45ab	0.54a	1.97a	5.60	18.56a	2.17	6.28	17.34b
6%	0.36	0.45a	0.59a	0.36	0.46a	0.50ab	1.99a	5.43	19.40a	2.39	6.98	20.92a
9%	0.37	0.43ab	0.52b	0.35	0.41bc	0.45b	1.76ab	5.14	17.28ab	2.19	6.37	13.93c
P-Value	0.131	0.003	0.001	0.338	0.001	0.001	0.002	0.374	0.008	0.352	0.076	0.001
SE (±)	0.020	0.012	0.015	0.011	0.016	0.010	0.094	0.453	1.154	0.172	0.451	1.216
Interaction												
V* GS	0.551	0.119	0.131	0.697	0.478	0.268	0.141	0.013	0.765	0.418	0.392	0.304
V*R	0.300	0.498	0.377	0.096	0.944	0.600	0.101	0.374	0.314	0.734	0.351	0.391
TA*R	0.106	0.166	0.224	0.104	0.269	0.202	0.398	0.479	0.404	0.508	0.904	0.220
V* GS*R	0.319	0.377	0.133	0.762	0.776	0.411	0.736	0.695	0.211	0.866	0.978	0.644

Means along the same column with unlike letter (s) are significantly different at 5% level of probability.

TABLE 6: INTERACTION BETWEEN VARIETY AND GROWTH STAGE OF FOLIAR APPLIEDKAOLIN ON CROP GROWTH RATE OF SOYBEAN AT BUKAND KADAWA DRY SEASON.

	Growth Stage 9WAS			Growth Stage 12WAS		
	BUK			Kadawa		
	NODIN	FLOIN	PODIN	NODIN	FLOIN	PODIN
Variety TGX1835-10E	4.85ab	4.56ab	6.10a	13.72b	20.10ab	25.71a
TGX1955-4F	3.82b	6.02a	6.16a	16.89ab	18.61ab	17.85ab
SE (±)	0.443			2.229		

Means with unlike letter (s) are different at 5% level of probability. NODIN= node initiation, FLOIN = flower initiation and PODIN= pod initiation.

VII. GRAIN YIELD (KGHA^{-1})

Grain yield as affected by variety, growth stage for application of kaolin and its rate at BUK and Kadawa during the 2019 dry season are presented in (Table 7). At Kadawa result indicated thatTGX1955-4F produced significantly (P≤ 0.05) higher grain yield (2785.8 kgha^{-1})than TGX1835-10E

(2380.26 $kgha^{-1}$). However effect of kaolin application at growth stage shows higher grain yield in application at flower and pod initiation at BUK.Put together at Kadawa application at pod initiation recorded significantly ($P \leq 0.05$) higher yield and shows similarity in grain yield with application of kaolin at flower initiation. Lower grain yield was recorded in application at node initiation and indicated similarity in grain yield recorded in application at flower initiation.

At BUK, kaolin rate indicated significantly ($P \leq 0.01$) highest grain yield with application of 3% kaolin and shows similarity with application of 6% kaolin and were followed by application of 9% kaolin. Lower grain yield at the control and indicated similarity in application of 9% kaolin. At Kadawa, application of 6% kaolin produced significantly ($P \leq 0.01$) highest in grain yield followed by application of 3%. Lower grain yield was in application of 9% kaolin and indicated similarity in plants treated at the control. No significant interaction recorded from the trials.

Fodder Yield ($kgha^{-1}$)

The influence of variety, kaolin application at growth stage, kaolin rate and its rates on fodder yield of soybean at BUK and Kadawa during the 2019 dry seasons is presented in (Table 7). Variety and kaolin application at growth stage recorded non-significant effect across locations.

At BUK location, application of 6% produced significantly ($P \leq 0.01$) highest fodder yield and indicated statistical similarity with application of 3% kaolin. Lower fodder yield with application of 9% kaolin and control shows statistical similarity with 3% treated plants.At Kadawa, application of 3 and 6% kaolin produced significantly ($P \leq 0.01$) highest fodder yield followed by application of 9% and lower from the control.

TABLE 7:GRAIN YIELD ($KGHA^{-1}$) OF SOYBEAN AS AFFECTED BY VARIETY, GROWTH STAGE OF FOLIAR APPLIED KAOLIN AND ITS RATE AT BUK AND KADAWA DURING THE 2019 DRY SEASON.

Treatment	Grain Yield ($kgha^{-1}$)		Fodder Yield ($kgha^{-1}$)	
	BUK	Kadawa	BUK	Kadawa
Variety (V)				
TGX1835-10E	2527.8	2380.2b	5765.5	5986.5
TGX1955-4F	2898.6	2785.8a	6833.7	6718.4
P-Value	0.148	0.038	0.239	0.458
SE (±)	161.41	81.612	628.40	768.48
Growth Stage (GS)				
Node Initiation	2305.7b	2259.2b	6331.7	6197.5
Flower Initiation	2805.3a	2635.5ab	6616.7	6938.9
Pod Initiation	3028.6a	2854.4a	5950.4	5921.0
P-Value	0.001	0.026	0.501	0.229
SE (±)	123.12	174.54	551.10	588.51
Kaolin Rate (R)				
0%	2326.7c	2396.6bc	5441.5b	4664.8c
3%	3174.7a	2644.1b	6555.5ab	7508.1a
6%	2846.9ab	3010.7a	7564.3a	7174.9a
9%	2504.5bc	2280.7c	5637.1b	6062.0b
P-Value	0.001	0.001	0.001	0.005
SE (±)	184.94	131.18	439.38	376.13
Interaction				
V* GS	0.155	0.8749	0.358	0.229
V*R	0.286	0.6194	0.306	0.067
GS *R	0.867	0.1125	0.879	0.499
V* GS *R	0.791	0.1469	0.434	0.575

Means along the same column with unlike letter (s) are different at 5% level of probability

Discussion

Response of Soybean Varieties

Revealed from the study, variety recorded significant differences in plant height (cm), number of branches plant-1, leaf area index plant-1, crop growth rate and grain yield andwere attributed to the ability of one variety to utilize the input resources and new technology employed more efficient than the other.However the variation could be due effect of season in that one variety was more responsive to dry season environment than the other during crop growing cycle. Put together could be due the effect of genetic make-up of the variety.This was in agreement with assertion made by Richburg et al. (2006) who stated that varieties behaved differently due to differences in their genetic makeup as well as response to soil water use efficiency and even from year to year or from field to field. This was also in line with assertion made by Waston (1952) that development of crop plant and their physiological processes depend upon the plant genetic make-up and environmental factors; for instance the numbers of tillers in millet depend upon the cultivar and genetic constitutions of the crop. In addition could also be due to effect offoliar application of kaolin which is new management practice which was in agreement withTaiz and

Zeiger (2002) that different water savings for increasing water use efficiency can be achieved by careful management.Response to Kaolin Application at Growth Stage

Significance differences were recorded from irrigated soybeans due to foliar applied kaolin at growth stage.More number of branches plant-1, wider leaf area index plant-1, crop growth rate, fodder and grain yield are recorded due to kaolin application at flower and pod initiation and this could be as a result of kaolin work which reduced high rate of transpiration (stress) since the crop at the stages had more number of leaves couple with higher solar radiation. This could be due to kaolin application at higher peak of crop growth and development and lower number of branches plant-1 in kaolin application at node initiation could be due crop was at early development stage and reposes could be on plant height, number of leaves and leaf sizes. Howevernon-significant effect in application at pod initiation could be due to crop entered reproductive phase. This was in agreement withTaiz and Zeiger (2002) who stated that different water savings for increasing water use efficiency can be achieved by careful management.Put together, could be due to established rooting system, number branches plant-1, wider or broader leaves, wider leaf area index hence more lighter intercept for photosynthesis, in addition to light interception, nutrients uptake which affect the growth hormones are optimum at the stage. The lower growth parameters recorded in application at node could be due to shorter plants and lower number leaf plant-1narrow leaf at early stage of growth and response could be in next morphological features or stage.

Response of Soybean to Kaolin Rates

The result indicated that application of 3 and 6% kaolin rates significantly recorded taller plant, number of branches plant-1, leaf area index plant -1, crop growth rate,grain and fodder yield and lower at control and 9% rates. This indicated that kaolin as a substance for water saving and heat load reduction work better at optimum rate and this was in line with assertion made by (El-mohsen et al. (2013) who reported that kaolin at 3% was more effective compared 5%.Lower effect recorded at 9% rate was attributed to negative effect of coating that was formed by thick layer of kaolin and its effect was found to affected crop performance due to curtail photosynthesis on overcast days when light are limited. This was in line with the assertion made by Davenport, et al. (1969) that coatings formed by kaolin on leaves surfaces may curtail photosynthesis on overcast days when light is limited. From the control rate lower effects were recorded and were attributed to stress due no application of kaolin and more heat load on leaf surfaces thereby causing higher transpiration rate. Higher rate of transpiration is stress which lead to cells flaccid, wilting of leaves death of plant. Significantly interactionsbetween variety, growth stage of foliar applied kaolin and kaolin ratescould be as a result of responses from variety, growth stage and kaolin rate.

Interaction

Variety and Growth Stage of Foliar Applied Kaolin

Interaction of variety and growth stage of foliar applied kaolin that indicated significant effect in recorded growth parameters and could be as a result of genetic differences between the two varieties and effect on management practices which affected the response of the two varieties to application of kaolin at growth stage of irrigated soybean.This was in agreement withthe statement of Taiz and Zeiger (2002) who reported that different water savings for increasing water use efficiency can be achieved by careful management.

Variety and Kaolin Rate

Interaction of variety and kaolin rates significantly indicated higher response to kaolin rate than the other in the measured growth parameters and could be due to effect of foliar sprayed kaolin. A similar report was made by Rania et al. (2018) who stated that in comparison to the control, foliar spraying of kaolin especially at the rate of 6% caused significant increase in seeds yield during the two growing seasons.

Variety and Growth Stage of Foliar Applied Kaolin and its Rate

Interaction of variety, kaolin rates and growth stage of foliar applied kaolin had significantly recorded effect in growth parameters as a result of variety responded to foliar applied kaolin, growth stage and optimum rates. This was in line with assertion made by; Glenn et al.(2005), Shellie and Glenn, (2008) and Glenn, (2009); Roussos et al.(2010); Denaxa et al. (2012) that the effectiveness of kaolin is linked plant species and cultivars. It was also in agreement withTaiz and Zeiger (2002) who stated that different water savings for increasing water use efficiency can be achieved by careful management.

Conclusion

The findings of the trial revealed that varieties, application at flower and pod initiation,3 and 6% kaolin indicated higher crop performances across sampling periods and locations.

Recommendation

Application of 3% kaolin rate could also recommended for soybeans production in areas with low heat load (low temperature) on leaf surfaces and 6% kaolin rate in areas with higher heat load (higher temperature) on leaf surfaces.

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