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# Effect of Foliar Applied Kaolin on Leaves Transpiration Loss of Soybean [*Glycine max* (L.) Merrill] Under Irrigation in Sudan Savanna of Nigeria

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## ABSTRACT

**A trial was conducted in 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, Kaduna (11˚ 38'.40.3" N 8˚ 25' 53.9" E) 498 m elevation during the hot of dry season of 2019 in the Sudan savanna of Nigeria to evaluate the effect of foliar applied kaolin (antitranspirant) on leaves water loss (transpiration) of soybean [*Glycine max* (L.) Merrill] under irrigations. 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 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 included plant height (cm), leaf area index plant$^{-1}$ at 6, 9 and 12WAS, dry matter (g), transpiration loss (mls), hundred seed weight (g) and grain yield (kgha$^{-1}$) 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. Variety and application at growth stage recorded non-significant effect due to kaolin application. Application of 9% kaolin indicated lowest water loss through leaves**

**transpiration and highest from the control rate. Application of 3 % kaolin could be recommended for soybean production in area with low heat load (low temperature) on leaf surfaces within the growing cycle of the crop and 6% rate in area with higher heat load (higher temperature) on leaf surfaces.**

**Keywords:** Hot dry season, variety, growth stage, kaolin rate and transpiration loss.

## INTRODUCTION

Transpiration in growing plant is a way of water escape from leaves through the stomatal opening under which higher rate is a stress which need control measures without which can affect crop performance and final yield depending on the severity, stage of crop development it occurs and time taken. This assertion was in line with one made by Shah Fahad *et al.* (2017) who reported that drought and heat stress cause significant reduction in growth and yield of several important crops; however, the extent of damage depend upon crop growth stage and severity of the stress. It can result in water scarcity that can damage the plant due to desiccation or loss of turgor and many other physiological abnormalities. It also causes wilting of the leaves and results in stunted growth of the plants. This assertion was in line with the report of (Fathi and Tari, 2016) that higher transpiration affects plant growth and development; decreases water potential, cell division, net photosynthesis, and protein synthesis; changes hormonal balance of the main plant tissue and also leads to a loss in yield by reducing total biomass, relative water content, and chlorophyll content. During the process of transpiration, water molecules in the plant tissues are removed from the aerial parts of the plant (Taiz and Zeiger, 2002).

However higher transpiration rate can cause cell flaccid and is a stress which has something to do with the development of plants and is enough to cause adverse effects on soybean growth and final yield under hot dry season of Sudan savanna of Nigeria which support better crop performances. Although plant through various mechanisms increases resistance to drought and various other artificial means to increase resistance to drought and manage transpiration rate may be employed. 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). It in view of effect of higher transpiration rate on soybean which has a greater number of leaves and kaolin when applied on the leaves mitigate the impact was used to evaluate its impact on water loss through transpiration in soybean production under irrigation.

## MATERIALS AND METHODS

The experiment was conducted during the hot dry seasons of 2019 in 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 of Institute for Agricultural Research, Ahmadu Bello University situated at Kadawa, Kano (11° 38'.40.3" N 8° 25' 53.9" E) 498 m elevation; representing the two locations used within the Sudan savannah ecological zone of Nigeria.

**Soil Sampling and Analysis**

Soil samples from each of the locations were collected randomly from 0-30cm depth using soil auger. It involved five sampling units from each of the three replications making total of fifteen units. It was then mixed thoroughly to have a uniform mixture in each of the location from which a composite sample was collected and analyzed to determine the physical and chemical properties using procedure described by through Black (1965).

**Treatments and Experimental Design**

Treatments consisted of two varieties of soybean (TGX1835-10E and TGX1955-4F), three growth stages (node initiations, flower initiations and pod initiation) and four rates of kaolin (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 of foliar applied kaolin in sub plots and kaolin rates in sub-sub plots.

**Meteorological Data**

Meteorological data were collected from the nearest meteorological data station (Soil Science Department, Bayero University, Kano).

**Planting Materials**

The seeds of the two varieties, TGX1835-10E and TGX1955-4F were obtained from the Institute for Agricultural Research, Kano Station. They are varieties good for Sudan savannah zone, brown in color with grain size of 6-7mm. They are early maturing (85- 100 day), high yielding, low shattering and resistance to pest and diseases. Previous crops grown, roaming animals, water-logging, water source and others were considered during site selection. The sites were cropped with maize in the last two years and are flat. All unwanted materials were cleared and removed. Fields were watered, ploughed, ridged and prepared into fine tilth with deep loose soil for good seed-soil contact and better development. The field of each of the experimental site was marked out in to total size of 1150.5$m^2$. 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 (15$m^2$) and net plot sizes (two inner rows) 4.5$m^2$.Before sowing, seeds were treated with soybean nitrogen fixing bacteria (*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. Through surface flooding, irrigation water was conveyed in to basin of research plots. Interval of four days between irrigation was maintained in BUK and 7day in Kadawa due to variation in water table and withdrew at pods maturity. Four to five seeds per hole were sown at a depth of about 4cm at inter and intra-row spacing of 0.75 and 10cm respectively, it was then thinned down to 4 plants per stand at 3WAS and supplying was done at 10 DAS. Weeding was manually done using hoe at 4 and 8WAS.

Fertilizer was applied at recommended rate of phosphorus 30 $kgha^{-1}$ in the form of single super phosphate fertilizer (SUPA) (3 × 50 kg bags) in addition to 2½ × 50 kg bags of compound fertilizer were applied. At maturity the pod is straw colored, outer rows were harvested first by cutting the plant from the ground level fallowed by sample plant and net plots for data collections. Properly dried sampled and net plot yield were manually threshed through putting

inside sacks and beating with stick. Winnowing to remove the seeds from the debris followed and total fodder collected and weighed and recorded.

**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 was 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**

**Plant Height (Cm):**

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

**Leaf Area Index Plant$^{-1}$:**

Leaf areas were measured and the values were computed in to leaf area index 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).

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

**Dry Matter Weight Plant$^{-1}$ (g):**

It was obtained after uprooting four plants from border rows, roots rinsed in water dried, wrapped in paper wrapped, oven dried at 70$^{o}$c for 12 hours and weighted average recorded.

**Determination of Water Loss through Transpiration (mls):**

About 8mls of water were filled in 10mls syringe. Uniform cuttings with three leaves from each treated and untreated plots were then inserted about 3cm deep into the syringes. One mls of oil was then dropped in to the syringes to form a surface thin layer to prevent water loss. The syringes were carefully bored in to cork to prevent water loss by conduction from the back of

the syringe. At this stage initial reading of the water + oil volume of the syringe was taken and recorded. The set-up has then placed by the side of plants in each plot for three hours and final readings was taken and recorded. The difference between initial reading and final reading was then taken which represent the water loss by the plants in each plot. The procedure was carried out 2 days after kaolin application at soil water at filled capacity and repeated two times and average recorded.

**100 Grain Weight (g):**
One hundred grains from tagged plants were weighed and recorded.

**Grain Yield (kgha$^{-1}$):**
Termex 16 moisture regulator (15% MC) was used to reduce moisture content in grain yield of tagged plants measured in gram and extrapolated in kilogram per hectare using the formula below;

$$\text{GY} = \frac{\text{Grain Yield (kgha}^{-1}\text{) x 10,000}(m^2)}{Plot\ Area\ (m^2)}$$

**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

**Plant Heights (cm)**
The effect of variety, application at growth stage and kaolin rates on plant heights (cm) of soybean at BUK and Kadawa during the 2019 dry season is presented in (Table 1). The result recorded no significant effect from variety across the sampling periods and locations except at 9WAS at Kadawa TGX1835-10E produced significantly (P≤ 0.01) taller plants than TGX1955-4F. Put together foliar application of kaolin at growth stage indicated no significant effect across sampling period and locations.

At BUK, application of 6% at 9 and 12WAS produced significantly (P≤ 0.01) tallest plants than those treated with 3 and 9% kaolin and shortest plant was observed at the control. At Kadawa, application of 6% kaolin at 9WAS produced significantly (P≤ 0.01) taller plants which are similar in height with those treated with 3% kaolin. However, application of 9% kaolin produced shorter plants and indicated similarity in plants height treated with 3% kaolin and shortest plant was recorded with the control. At 12WAS, application of 6% kaolin produced significantly (P≤ 0.01) taller plants than 3% kaolin. Similarly, application of 9% kaolin recorded shorter plants and indicated similarity with those treated with 3% kaolin. However, shortest plants recorded at the control shows statistical similarity in plant height with plants treated with 9% kaolin. The study shows non-significant interaction across sampling periods and locations.

**Leaf Area Index Plant$^{-1}$**

The effect of variety, growth stage of foliar applied kaolin and its rate on leaf area index plant$^{-1}$ of soybean at BUK and Kadawa during the 2019 dry season is presented in (Table 1). The result shows that variety statistically produced plants with same leaf area index plant$^{-1}$ across the sampling periods and locations except at 12WAS at BUK TGX19555-4F significantly (P≤ 0.05) superseded TGX1835-10E in leaf area index plant$^{-1}$. Effect of kaolin application at growth stage at 6WAS at BUK indicated significantly (P≤ 0.05) wider leaf area index plant$^{-1}$ in kaolin application at node and pod initiations and indicated similarity in leaf area index plant$^{-1}$ with kaolin application at flower initiation. At 9WAS wider leaf area index plant$^{-1}$ was significantly (P≤ 0.01) with application at flower initiation and shows similarity with application at pod initiation.

Lower leaf area was with kaolin application at node initiation and was statistically similar in plants treated at pod initiation. At 12WAS application at pod initiation recorded significantly (P≤ 0.01) higher leaf area index and were statistically similar to application at flower initiation. Lower leaf area index was recorded for application at node initiation and statistically showed same leaf area were in application at flower initiation.

In BUK, application of 3 and 6% kaolin at 9WAS produced significantly (P≤ 0.01) higher leaf area index and were statistically similar in plants treated with 9% kaolin. Lower leaf area was recorded at control and shows similarity in leaf area index in plants treated with 9% kaolin. Application of 3% kaolin at 12WAS recorded significantly (P≤ 0.01) higher leaf area index which was statistically similar in leaf area index in plants treated with 9% kaolin. Lower leaf area index was recorded in application of 9% kaolin and statistically indicated similar leaf area index with application of 9% kaolin. Lowest leaf area index recorded at control shows statistical similarities with application of 9% kaolin. Significance interactions were recorded at 6WAS and 9WAS.

In Kadawa, 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. At 12WAS, higher leaf area index was recorded with application of 6%, followed by 3% and lowest were at control and 9% kaolin. No significant interaction was recorded across the seasons during the trial.

Interaction between variety and application at growth stage in BUK, was recorded significant (P≤ 0.01) at 6WAS in (Table 2). Highest leaf area was recorded for TGX1955-4F with application at flower and pod initiations and was statistically similar to leaf area index of TGX1835-10E across all the application stages tested. Lower leaf area index with application at node initiation in TGX1955-4F was statistically similar with leaf area index across all the application stages of TGX1835-10E.

Interaction between variety and application at growth stage in BUK, recorded significant (P≤ 0.05) at 9WAS in (Table 2). TGX1955-4F has higher leaf area index with application at pod initiation and was statistically similar with leaf area index of TGX1835-10E across the

application stages treated and at flower initiation of TGX1955-4F. Lower leaf area index of TGX1955-4F with application at node initiation was statistically similar with leaf area index recorded with application at all growth stage treated except TGX1955-4F which was higher in leaf area index with application at pod initiation.

**Table 1: Plant Height (cm) and Leaf Area Index Plant$^{-1}$ of Soybean as Affected by Variety, Growth Stage of Foliar Applied Kaolin, Kaolin and its Rate at BUK and Kadawa during the 2020 Dry Season.**

| Treatment | BUK (PHT) | | | Kadawa (PHT) | | | BUK (LAI) | | | Kadawa (LAI) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6WAS | 9WAS | 12WAS | 6WAS | 9WAS | 12WAS | 6WAS | 9WAS | 12WAS | 6WAS | 9WAS | 12WAS |
| **Variety (V)** | | | | | | | | | | | | |
| TGX1835-10E | 19.33 | 41.62 | 76.04 | 24.73 | 48.92a | 72.87 | 0.38 | 0.43 | 0.48b | 0.42 | 0.51 | 0.63 |
| TGX1955-4F | 18.93 | 40.39 | 70.41 | 22.22 | 45.28b | 74.24 | 0.40 | 0.45 | 0.52a | 0.41 | 0.55 | 0.66 |
| P-Value | 0.339 | 0.638 | 0.298 | 0.142 | 0.027 | 0.880 | 0.226 | 0.266 | 0.005 | 0.854 | 0.411 | 0.139 |
| SE (±) | 0.327 | 2.228 | 4.041 | 0.062 | 0.632 | 7.991 | 0.015 | 0.016 | 0.014 | 0.011 | 0.038 | 0.010 |
| **Growth Stage (GS)** | | | | | | | | | | | | |
| Node Initiation | 19.77 | 41.69 | 69.07 | 22.87 | 49.48 | 76.43 | 0.37a | 0.43b | 0.47b | 0.41 | 0.51 | 0.65 |
| Flower Initiation | 18.65 | 41.36 | 75.58 | 24.10 | 45.58 | 73.82 | 0.39ab | 0.46a | 0.50ab | 0.42 | 0.55 | 0.66 |
| Pod Initiation | 18.98 | 39.97 | 75.03 | 23.47 | 46.05 | 70.43 | 0.41a | 0.45ab | 0.52a | 0.41 | 0.53 | 0.63 |
| P-Value | 0.463 | 0.807 | 0.337 | 0.799 | 0.151 | 0.497 | 0.015 | 0.007 | 0.012 | 0.483 | 0.084 | 0.241 |
| SE (±) | 0.886 | 2.750 | 4.570 | 1.817 | 1.942 | 4.870 | 0.023 | 0.023 | 0.011 | 0.012 | 0.017 | 0.014 |
| **Kaolin Rate (R)** | | | | | | | | | | | | |
| 0% | 19.68 | 34.38c | 60.53c | 23.99 | 40.47c | 66.88c | 0.38 | 0.42b | 0.47c | 0.41 | 0.49c | 0.59c |
| 3% | 18.66 | 41.02b | 79.83b | 22.10 | 49.16ab | 73.79b | 0.39 | 0.46a | 0.54a | 0.42 | 0.54ab | 0.67b |
| 6% | 19.18 | 49.31a | 86.49a | 23.19 | 52.56a | 82.74a | 0.40 | 0.46a | 0.51ab | 0.42 | 0.57a | 0.72a |
| 9% | 19.02 | 39.27b | 66.06c | 23.59 | 46.17b | 70.82bc | 0.39 | 0.44ab | 0.47bc | 0.41 | 0.51bc | 0.61c |
| P-Value | 0.316 | 0.001 | 0.001 | 0.885 | 0.001 | 0.001 | 0.564 | 0.004 | 0.001 | 0.558 | 0.001 | 0.001 |
| SE (±) | 0.539 | 1.423 | 3.135 | 1.246 | 1.556 | 2.367 | 0.012 | 0.011 | 0.013 | 0.010 | 0.016 | 0.021 |
| **Interaction** | | | | | | | | | | | | |
| V* GS | 0.628 | 0.686 | 0.902 | 0.928 | 0.108 | 0.609 | 0.002 | 0.055 | 0.197 | 0.821 | 0.112 | 0.663 |
| V*R | 0.569 | 0.727 | 0.427 | 0.823 | 0.663 | 0.565 | 0.344 | 0.610 | 0.467 | 0.114 | 0.137 | 0.665 |
| GS*R | 0.246 | 0.921 | 0.848 | 0.731 | 0.889 | 0.441 | 0.851 | 0.139 | 0.163 | 0.586 | 0.779 | 0.792 |
| V* GS*R | 0.412 | 0.177 | 0.390 | 0.656 | 0.109 | 0.143 | 0.312 | 0.458 | 0.463 | 0.269 | 0.567 | 0.422 |

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

**Table 2: Interaction between Variety and Growth Stage of Foliar Applied Kaolin on Leaf Area Index Plant$^{-1}$ of Soybean at 12WAS at BUK Dry Season.**

| BUK | Growth Stage 6WAS | | | Growth Stage 9WAS | | |
|---|---|---|---|---|---|---|
| | NODIN | FLOIN | PODIN | NODIN | FLOIN | PODIN |
| **Variety** | | | | | | |
| TGX1835-10E | 0.39ab | 0.36ab | 0.38ab | 0.44ab | 0.45ab | 0.46ab |
| TGX1955-4F | 0.36b | 0.413a | 0.43a | 0.43b | 0.46ab | 0.49a |
| SE (±) | 0.012 | | | 0.012 | | |

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

## Dry Matter Weight (g)

Influence of variety, growth stage of foliar applied kaolin and its kaolin rate on dry matter weight (g) plant $^{-1}$of soybean at BUK and Kadawa during the 2019 dry season is presented in

**(Table 3).** At Kadawa TGX1955-4F produced significantly (P≤ 0.05) higher dry matter weight than TGX1835-10E. Application at node and flower initiations indicated significantly (P≤ 0.05) more dry matter weight than application at pod initiation although was statistically similar in dry matter weight in at pod initiation. Effect of kaolin rate in BUK 2019 showed significantly (P≤ 0.01) higher dry matter weight with application of 3 % than control and 9% but was statistically similar to plants treated with 6% kaolin. At Kadawa, application of 3 and 6% kaolin produced significantly higher dry matter weight than application of 9% and the control.

## Transpiration Loss (mls)

The influence of variety, growth stage of foliar applied kaolin and kaolin rate in transpiration loss (mls) of soybean at BUK and Kadawa during the 2019 dry season is presented in (**Table 3**). The study indicated that variety and application at growth stage had no significant influence on transpiration loss across the locations. Effect of kaolin rate recorded significantly (P≤ 0.01) highest water loses (ml) through transpiration at control followed by application of 3% kaolin which was statistically similar in water loss recorded with application of 6% kaolin across locations. Lowest water loss through transpiration (ml) recorded with application of 9% kaolin across locations were statistically similar with water loss observed with application of 6% kaolin in the two locations.

**Table 3: Dry Matter Weight Plant $^{-1}$ (g) and Transpiration Loss (mls) of Soybean as Affected by Variety, Application at Growth Stage and Kaolin Rate at BUK and Kadawa during 2020 Dry Season.**

| Treatment | Dry Matter (12WAS) | | | Average Transpiration Loss | |
|---|---|---|---|---|---|
| | BUK | Kadawa | | BUK | Kadawa |
| **Variety (V)** | | | | | |
| TGX1835-10E | 68.41 | 71.55b | | 2.51 | 2.74 |
| TGX1955-4F | 78.93 | 91.05a | | 2.58 | 2.52 |
| P-Value | 0.187 | 0.021 | | 0.611 | 0.440 |
| SE (±) | 5.335 | 2.725 | | 0.121 | 0.229 |
| **Growth Stage (GS)** | | | | | |
| Node Initiation | 69.93 | 85.93a | | 2.58 | 2.69 |
| Flower Initiation | 80.28 | 83.21a | | 2.56 | 2.58 |
| Pod Initiation | 70.79 | 74.76ab | | 2.50 | 2.62 |
| P-Value | 0.244 | 0.052 | | 0.923 | 0.872 |
| SE (±) | 6.246 | 3.954 | | 0.212 | 0.201 |
| **Kaolin Rate (R)** | | | | | |
| 0% | 65.22b | 73.77b | | 3.48a | 3.66a |
| 3% | 84.53a | 87.11a | | 2.37b | 2.54b |
| 6% | 77.97ab | 90.29a | | 2.29bc | 2.26bc |
| 9% | 66.94b | 74.03b | | 2.03c | 2.07c |
| P-Value | 0.001 | 0.001 | | 0.001 | 0.001 |
| SE (±) | 5.021 | 4.153 | | 0.157 | 0.174 |
| **Interaction** | | | | | |
| V* GS | 0.660 | 0.420 | | 0.858 | 0.721 |
| V*R | 0.359 | 0.205 | | 0.891 | 0.466 |

| | | | | |
|---|---|---|---|---|
| GS *R | 0.175 | 0.089 | 0.926 | 0.634 |
| V* GS *R | 0.219 | 0.106 | 0.868 | 0.845 |

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

**Hundred Seed Weight (g)**

Effect of variety, application at growth stage of foliar applied kaolin and kaolin rate on hundred seed weight of soybean at BUK and Kadawa during the 2019 dry season is presented in (**Table 4**). The study indicated that variety had no significant effect on hundred seed weight across the locations. Effect of kaolin application at growth stage at Kadawa produced significantly (P≤ 0.01) higher hundred seed weight with application at pod initiation and lower with application at node and flower initiation.

Effect of application kaolin rate at Kadawa recorded significantly (P≤ 0.01) highest hundred seed weigh with application of 3 and 6% kaolin and lower hundred seed weight with application of 9% kaolin and the control.

**Interaction**

Interaction between application at growth stage and kaolin rates in (Table 5) at BUK showed that significantly (P≤ 0.05) highest hundred seed weight was recorded with application of 6% kaolin at pod initiation. It was statistically similar in hundred seed weight with application of 3% at flower and pod initiation; 6% at flower initiation and 9% at pod initiation. Lowest hundred seed weight was recorded across growth stage at control.

**Grain Yield (kgha$^{-1}$)**

The grain yield as affected by variety, application at growth stage and kaolin rate at BUK and Kadawa during the 2019 dry seasons is presented in (Table 4). Results of the study indicated that grain yield was not significantly affected by variety across location except at Kadawa TGX1955-4F produced significantly (P≤ 0.05) higher grain yield (2785.8 kgha$^{-1}$) than TGX1835-10E (2380.2 kgha$^{-1}$). At Kadawa effect of kaolin application at growth stage recorded significantly (P≤ 0.01) highest grain yield with application at flower and pod initiation and lower at node initiation. However, application at pod initiation in at Kadawa, recorded significantly (P≤ 0.05) highest yield and indicated similarity with application of kaolin at flower initiation. Lower grain yield was recorded with application at node initiation and had statistical similarity with application of kaolin at flower initiation. Effect of kaolin rate on grain yield at BUK produced significantly (P≤ 0.01) higher grain yield with application of 6% kaolin and shows statistical similarity in grain yield with application of 3% kaolin and were followed by application of 9 % kaolin. Lowest grain yield at the control shows similarity with application of 9% kaolin.

At Kadawa, application of 6% kaolin produced significantly (P≤ 0.01) highest grain yield followed by application of 3%. Lowest grain yield was recorded with application of 9% kaolin and indicated similarity in plant treated with control. No significant interaction recorded from the seasons.

**Table 4: Hundred Seed Weight (g) and 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 | Hundred Seed Weight (g) | | Grain Yield (kgha$^{-1}$) | |
|---|---|---|---|---|
| | BUK | Kadawa | BUK | Kadawa |
| **Variety** | | | | |
| TGX1835-10E | 15.17 | 15.09 | 2295.8 | 2380.2b |
| TGX1955-4F | 14.79 | 15.01 | 2508.9 | 2785.8a |
| P-Value | 0.403 | 0.712 | 0.459 | 0.038 |
| SE (±) | 0.362 | 0.209 | 234.38 | 81.612 |
| **Growth Stage** | | | | |
| Node Initiation | 14.77 | 14.59b | 2028.2b | 2259.2b |
| Flower Initiation | 14.78 | 14.86b | 2569.9a | 2635.5ab |
| Pod Initiation | 15.40 | 16.10a | 2608.9a | 2854.4a |
| P-Value | 0.186 | 0.005 | 0.012 | 0.026 |
| SE (±) | 0.353 | 0.247 | 162.05 | 174.54 |
| **Kaolin Rate (% w/v)** | | | | |
| 0% | 14.72 | 15.10b | 2120.9c | 2396.6bc |
| 3% | 15.01 | 15.39a | 2615.0ab | 2644.1b |
| 6% | 15.27 | 15.53a | 2688.4a | 3010.7a |
| 9% | 14.92 | 14.77b | 2185.1bc | 2280.7c |
| P-Value | 0.087 | 0.001 | 0.001 | 0.001 |
| SE (±) | 0.239 | 0.220 | 181.73 | 131.18 |
| **Interaction** | | | | |
| V* GS | 0.718 | 0.630 | 0.211 | 0.8749 |
| V*R | 0.087 | 0.204 | 0.481 | 0.6194 |
| GS *R | 0.170 | 0.038 | 0.645 | 0.1125 |
| V* GS *R | 0.553 | 0.597 | 0.659 | 0.1469 |

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

**Table 5: Interaction between Growth Stage of Foliar Applied Kaolin and Kaolin Rate on Hundred Seed Weight (g) of Soybean at Kadawa 2019 Dry Season.**

| | **Rate** | | | |
|---|---|---|---|---|
| | 0% | 3% | 6% | 9% |
| **Growth Stage** | | | | |
| NODIN | 14.67c | 14.55c | 14.87bc | 14.28c |
| FLOIN | 14.25c | 15.33abc | 15.22abc | 14.65c |
| PODIN | 14.60c | 16.28ab | 16.52a | 15.38abc |
| SE (±) | | 0.380 | | |

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

## DISCUSSION

### Response of Soybean Varieties

The study indicated higher values from variety with respect to plant height (cm), leaf area index plant$^{-1}$, dry matter weight (g) and grain yield (kgha$^{-1}$). The response of variety to recorded growth and yield parameters could be due to effect of environmental factors, input and management practices which favored one variety to be more responsive than the other. It could also be to differences in their genetic composition. This was in agreement with the assertion made by Waston (1952) who stated that the 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. These factors however do vary in their effect from locations as well as from one species to another. Put together in agreement with the assertion made by Richburg *et al.* (2006) that varieties behaved differently due 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.

### Response of Soybean to Foliar Applied Kaolin on Growth Stage

Kaolin application at growth stage recorded significant differences on recorded leaf area index plant$^{-1}$, dry matter weight (g) hundred seed weight (g) and grain yield (kgha$^{-1}$). Effect of application at flower and pod initiation were higher than application at node initiation. This could be as a result of kaolin work which reduced high rate of transpiration (stress) since the crop at the stages had a greater number of leaves couple with higher solar radiation. This was in agreement with Taiz and Zeiger (2002) that different water savings for increasing water use efficiency can be achieved by careful management.This was supported by the statement made by Rosolem (2005) who reported that the water demand for soybean is highest at the initiation of flowering, but a water deficit from pod initiation (R3) until 50% yellow (R7) is the most critical stage for productivity.

### Response of Soybean to Rates of Foliar Applied Kaolin

The result of the study indicated that kaolin rate had significantly affected plant height (cm), leaf area index plant $^{-1}$, plant dry matter weight (g), transpiration loses, hundred seed weight (g) and grain yield (kgha$^{-1}$) of irrigated soybean. Application at 3 and 6% kaolin were higher than the control and 9% rate except in transpiration loses where control rate recorded significantly higher loses and lowest in application of 9% kaolin. This suggests that effectiveness of foliar applied kaolin was dependent upon optimum rate. This was supported by the finding of El-mohsen *et al.* (2013) who reported that 3% kaolin was more effective than 5% kaolin. Application 3 and 6% kaolin record higher value and could be due to low stress as a result optimum kaolin applied. Lower value recorded in application of 9% kaolin was attributed to negative effect of coating that was formed by thick dried solution of kaolin and its effect was found to affected crop performance due to curtail photosynthesis on overcast days when light is 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 was recorded and was attributed to stress due to lack of application of kaolin hence more heat load on leaf surfaces thereby causing higher transpiration rate. In contrast, application 9% kaolin rate recorded lowest water loses through transpiration and was attributed to negative effect of foliar applied kaolin that formed the thick

layer on leaf surface thereby reflected back solar radiation and or reduced heat load on leaf surface and this indicated better water use efficiency but it proved to be non-beneficial as it acted as protective layer, insulated and or coated the leaves as a result reduced sunlight access to internal structure. This could be the reasons for lower yield recorded in application of 9% kaolin. This indicated that kaolin as a substance for water saving and light reflection 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%. In another statement was supported by Segura-Monroy *et al.* (2015) who reported that foliar application sprays with kaolin improved the water use efficiency by reducing the leaf transpiration rate and the leaf temperature. Also stated kaolin applied at a high concentration reduces the availability of IPAR (Rosati *et al.,* 2006; Wünsche *et al.,* 2004; Shellie and King, 2013). At control rate water loses through transpiration was higher and was attributed to lack of treatment hence no part of the solar radiation was reflected back or reduced as such more heat load on leaf surface.

**Interaction**

**Variety and Growth Stage of Foliar Applied Kaolin:**

Interaction of variety and growth stage of foliar applied kaolin had produced plant with significantly wider leaf area index. The interaction recorded could be as a result of genetic differences between the two varieties which also affected the response of variety to kaolin application at growth stage. This assertion was in line with one made by Shah Fahad *et al.* (2017) who reported that drought and heat stress cause significant reduction in growth and yield of several important crops; however, the extent of damage depend upon crop growth stage and severity of the stress. In another statement plant response to drought stress generally varies from species to species depending on plant growth stage and other environmental factors (Demirevska *et al.,* 2009)

**Effect of Application at Growth Stage and Kaolin Rate:**

Application at growth stage and kaolin rate significantly shows interaction on hundred seeds weight (g) and was attributed to application of kaolin at one growth stage was more effective than the other stage and as well due to optimum rate of kaolin applied. This was supported by the findings of Rosolem (2005) stated that water demand for soybean is highest at the initiation of flowering, but a water deficit from pods initiation (R3) until 50% yellow (R7) is the most critical stage.

## CONCLUSION

The finding of the research, TGX1955-E recorded higher grain yield ($kgha^{-1}$) than TGX1835-4F. Kaolin application at pod initiation followed by at application at flower initiation recorded higher grain yield ($kgha^{-1}$) and lowest was from application at node initiation. However, application of 3 and 6% recorded higher grain yield ($kgha^{-1}$) and lower in application of 9% kaolin and the control. Put together application of 3% kaolin is recommended for soybean production in areas with low heat load (low temperature) on leaf surfaces within the growing cycle of the crop and 6% kaolin in areas with higher heat load (higher temperature) on leaf surface.

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