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Full Length Research Paper

Assessment of Nutrient Uptake on the Performance and Yield of Extra-Early Maize (*Zea mays L.*) Under two water Regimes in the Sudan Savannah of Nigeria

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Abstract

Two separate field trials were conducted during the 2005 rainy season and 2006 dry season at the Research Farm of the Institute for Agricultural Research (IAR), Kadawa in the Sudan Savannah of Nigeria to assess the nutrient uptake on the performance and yield of extra-early maize (Zea mays L.) under two water regimes. The treatments consisted of four NPK rates (0:0:0, 60:30:30, 120:60:60, and 180:90:90 Kg ha^{-1}) and one plant population (53,000 plants ha^{-1}). In 2005, the experiment was rain- fed while in 2006 during the dry season the experiment was irrigated. Under the two water regimes, the experiments were factorially combined and laid out in Randomised Complete Block Design with four replicates. The results showed that application of 60:30:30kgNPKha^{-1} was generally optimum for 100-grain weight and grain yield (1, 429.40 and 2, 929.60 kg ha^{-1} for rain-fed and irrigated plants respectively). When the grain yields were regressed against fertilizer rates, the response was quadratic and positively significant for the grain yields under the two water regimes. The regression analysis revealed that under rain-fed, grain yield was optimum (1,700 kg ha^{-1}) when 900 kg NPK ha^{-1} was applied while under irrigation, grain yield was optimum (3, 500 kg ha^{-1}) when 750 kg NPK ha^{-1} was applied. The result also showed that nutrient up-take in irrigated plants is higher than in plants under rain-fed and this translate to higher yield at all rates of NPK fertilizer.

Key words: - *Extra-Early Maize, NPK Fertilizer, irrigation and Grain yield*

Introduction

Maize (*Zea mays L.*) probably originated from Mexico or Central America from where it spread to other parts of the world including Latin America, the Caribbean, the United States, Canada and Africa. Maize is a cereal with very high yield potential and therefore valuable for nourishment of both human and animals. Maize is the most widely adapted and the third most important cereal of the world after wheat (*Triticum aestivum)* and rice (*Oryza sativa L.*) (Iken and Amusa, 2004).

Nigeria is the leading producer of maize in the West Africa sub-region. The Central Bank of Nigeria Annual Report (2007) and statement of accounts stated that 6.4 million tonnes of maize were produced in 2006.

It has been reported that maize has a wide range of uses more than any other cereal (Roy and Singh, 2002). The grain of maize is an important source of energy and it is consumed by human in various forms. The fresh immature grain is roasted or cooked and eaten directly (Roy and Singh, 2002). The dried grain is used for the preparation of porridge through the process of milling and boiling. The flour is made into paste and eaten as `tuwo' with soup. It is also used for the production of livestock feeds and in the industries for the production of spirits, alcohol, corn starch, beer among others. The fresh shoots are made into silage while the stalk is grazed by animals. The stalk is also used for building construction, fencing and mulching as well as source of fuel.

Weather is always known to regulates the heat and moisture supply of any growing site, has an effect on the transformation of materials, the growth of plants, nutrient uptake and thus on the influence of fertilizers (Kovács, 1982; Nagy, 1996, Drimba and Ertsey, 2003; Drimba *et al*., 2000). In areas that are poor in precipitation, irrigation guarantees yield. With irrigation, constant water supply and undisturbed physiological operation of plants can be ensured and water supply plays a significant role in the utilization of fertilizer active substances especially that of nitrogen.

The effect of fertilization increases with optimal water supply and decreases when harmful water excess is reached (Nagy, 2000, 2001). The irrigation and fertilization experiment result of Nagy (1997) have proved, that irrigation increases the efficiency of fertilization and that there is a strong correlation between fertilizer utilization and the water supply of plants. In irrigated treatment, which means a higher yield level, due to the positive correlation between irrigation and fertilization, the economic fertilizer doses are greater than without irrigation. In a similar vein, Hank and Frank (1951) have proved that irrigation increases the efficiency of fertilization. The efficiency of fertilizers also depends on agroecological conditions (Láng, 1981).

Szőke Molnár, (1977) confirmed that irrigation in general, especially in cases of drought, highly increase the yield of maize. Irrigation will be more essential in specific parts of the country for safe and intensive production of maize. The objective of the study was to determine the optimum NPK rates for the production of extra-early maize under rain-fed and irrigation.

Materials and Methods

The trials were conducted during the 2005 rainy season (July-Sept) and 2006 dry season (Jan-Mar) at the Research Farm of the Institute for Agricultural Research, Kadawa (11^o 39`N; 08^o 02'E and 500 meters above sea level) in the Sudan Savanna.

The treatments consisted of four rates of NPK fertilizer (0:0:0, 60:30:30, 120:60:60, and 180:90:90 Kg ha^{-1}) and plant population of 53,000 plants ha^{-1}. In 2005 during the rainy season, the plants were rain-fed while in 2006 the plants were irrigated three times in a week. In each of the experiment, the treatments were factorially combined and laid out in a Randomized Complete Block Design (RCBD) and replicated four times.

The gross plot size consisted of six rows of five metres length (4.5m x 5.0m = $22.5m^2$), while the net plot size was four inner rows of five metres length (3.0m x 5.0m = $15m^2$). The gap between each replication was 0.75m while that between plots was 0.5m.

In each season, using adjacent sites, the experimental sites were ploughed, and harrowed after which two seeds of 95 – TZEE – W (75 and 80 days to maturity) were sown manually per hole at an intra-row spacing of 25 cm and inter-row spacing of 75 cm on flats. The crop was later thinned to one plant per stand two weeks after sowing to give the required plant population of 53, 000plants ha^{-1}.

NPK-20:10:10 fertilizer was applied at the rate of 60:30:30, 120:60:60 and 180:90:90kg ha^{-1} in two split doses while the control was left unfertilized. The first dose was applied at 2WAS, while the second dose was applied at 6WAS by side placement at about 8-10cm away from the base of the plant. Manual hand weeding was done at 3 and 6WAS.

The data collected were subjected to statistical analysis of variance (ANOVA) using Statistical Analysis Software (SAS) and the significant treatment means were compared using the Duncan's multiple Range Test (Duncan 1955) while the grain yield was regressed against the fertilizer rates (Barr and Goodnight, 1972).

The optimum fertilizer rates for rain-fed, irrigation and the combined were determined using following formula;

$$Y = \frac{-b}{2c}$$

Y = Optimum fertilizer rate

b and c = regression constant.

Results

The effect of treatments on the number of cobs/stand of extra-early maize in rain-fed, irrigation and the combined is presented on **Table 1**. Under the rain-fed and the combined, zero NPK application produced significantly lower number of cobs/stand than other levels which were significantly at par. When the plants were irrigated, varying the fertilizer rate did not affect number of cobs/stand.

The significant effect of fertilizer rate on cob length of extra-early maize under the two water regimes and the combined is shown on **Table 2**. Application of fertilizer rate up to 120:60:60kgNPKha^{-1} produced longer cobs, further increase to 180:90:90kgNPKha^{-1} did not affect cob length significantly.

Table 3 shows the significant effect of fertilizer rate on cob diameter under the two water regimes and the combined data. Increasing fertilizer rate up to 120:60:60kgha^{-1} significantly increased cob diameter under the two water regimes and when the data was combined. However, when fertilizer was further increased to 180:90:90kgha^{-1} the parameter remained statistically unaffected.

Table 1. Effects of rates of NPK fertilizer on number of cobs/stand of extra-early maize grown under rain-fed and irrigation in Kadawa.

Treatment	Rain-fed	Irrigation	Combined
Fertilizer rate NPK (kg^{-1})			
0:0:0	1.02_b	1.00	1.01_b
60:30:30	1.20_a	1.00	1.10_a
120:60:60	1.26_a	1.00	1.13_a
180:90:90	1.24_a	1.00	1.12_a
SE (±)	0.03	0.03	0.03

Means within a column followed by the same letter do not differ significantly at 0.05 level of probability according to Duncan Multiple Range Test (DMRT)

Table 2 - Effects of rates of NPK fertilizer on cob length (cm) of extra-Early maize grown under rain-fed and irrigation in Kadawa.

Treatment	Rain-fed	Irrigation	Combined
Fertilizer rate NPK (kg^{-1})			
0:0:0	11.32_c	8.53_c	9.93_c
60:30: 30	12.17_b	11.14_b	11.66_b
120:60:60	13.42_a	12.52_a	13.13_a
180:90:90	13.78_a	13.52_a	13.25_a
SE (±)	0.41	0.31	0.40

Means within a column followed by the same letter do not differ significantly at 0.05 level of probability according to Duncan Multiple Range Test (DMRT)

Table 3 - Effects of rates of NPK fertilizer on cob diameter of extra-early maize grown under rain-fed and irrigation in Kadawa.

Treatment	Rain-fed	Irrigation	Combined
Fertilizer rate NPK (kg^{-1})			
0:0:0	3.04_c	3.21_c	3.13_c
0:30:30	3.42_b	3.38_b	3.40_b
120:60:60	3.70_a	3.73_a	3.72_a
180:90:90	3.75_a	3.79_a	3.79_a
SE ($\pm$)	0.07	0.04	0.06

Means within a column followed by the same letter do not differ significantly at 0.05 level of probability according to Duncan Multiple Range Test (DMRT)

The effect of fertilizer rates and water managements on the number of kernel rows/cob of extra-early maize is presented in **Table 4**. Under the two water managements and when the data was combined, control gave significantly lower number of kernel rows/cob than other NPK fertilizer rates that were statistically at par.

The effect of treatments on the 100- grain weight is presented on **Table 5.** Control gave significantly lower 100-grain weight than those from the applied NPK fertilizer rates while the applied rates did not differ in their 100-grain weights during the rainy season, when the plants were irrigated and when the two data was combined.

Grain yield ha^{-1} as influenced by rates of fertilizer and two water managements is shown on **Table 6**. In each of the water managements, increasing fertilizer rate from 0:0:0 to 60:30:30 $KgNPKha^{-1}$ increased grain yield, further increase to 120:60:60$KgNPKha^{-1}$ or 180:90:90$KgNPKha^{-1}$did not affects the parameter significantly. However, it was observed that when the data of the two water managements were combined, yield produced at 180:90:90$kgNPKha^{-1}$ was significantly more than for the control and 60:30:30 treatments. For the two water managements combined data, grain yield ha^{-1} values for the 120:60:60 and 180:90:90$KgNPKha^{-1}$were not significantly different.

Table 4. Effects of rates of NPK fertilizer on number of kernel rows/cob of extra-early maize grown under rain-fed and irrigation in Kadawa.

Treatment	Rain-fed	Irrigation	Combined
Fertilizer rate NPK (kg^{-1})			
0:0:0	13.33_b	13.60_b	13.46_b
60:30:30	14.61_a	14.80_a	14.71_a
120:60:60	14.97_a	14.60_a	14.78_a
180:90:90	14.25_a	14.25_a	14.25_a
SE ($\pm$)	0.18	0.28	0.23

Means within a column followed by the same letter do not differ significantly at 0.05 level of probability according to Duncan Multiple Range Test (DMRT)

Table 5. Effects of rates of NPK fertilizer on 100-grain weight of extra- early maize grown under rain-fed and irrigation in Kadawa.

Treatment	2005	2006	Combined
Fertilizer rate NPK (kg^{-1})			
0:0:0	19.99_b	19.88_b	19.94_b
60:30:30	22.20_a	23.42_a	22.81_a
120:60:60	22.75_a	22.89_a	22.83_a
180:90:90	22.50_a	24.56_a	23.40_a
SE ($\pm$)	0.60	0.52	0.56

Means within a column followed by the same letter do not differ significantly at 0.05 level of probability according to Duncan Multiple Range Test (DMRT)

Table 6. Effects of rates of NPK fertilizer on grain yield (kg ha^{-1}) of extra-early maize grown under rain-fed and irrigation in Kadawa.

Treatment	Rain-fed	Irrigation	Combined
Fertilizer rate NPK (kg^{-1})			
0:0:0	804.4_b	$1,103.7_b$	956.5_c
60:30:30	$1,429.4_a$	$2,929.6_a$	$2,179.5_b$
120:60:60	$1,609.1_a$	$3,282.9_a$	$2,449.3_{ab}$
180:90:90	$1,714.1_a$	$3,555.5_a$	$2,634.8_a$
SE ($\pm$)	192.69	206.31	199.62

Means within a column followed by the same letter do not differ significantly at 0.05 level of probability according to Duncan Multiple Range Test (DMRT)

Regression Analysis

When the grain yield was regressed against the NPK fertilizer rates (Figures 1, 2 and 3) the response was quadratic and positively significant for the two water managements and the combined years.

When the plants were rain-fed, the quadratic model had R^2 value of 0.2482 with optimum equation:

$YQ = 827.61 + 2.253x - 0.0014x^2$.

When the plants were irrigated, the quadratic had R^2 value of 0.6346 with optimum equation:

$YQ = 1172.4 + 6.469x - 0.0043x^2$.

The polynomial analysis of the combined data showed that the quadratic fitting curve with R^2 value of 0.301 had optimum regression equation of:

$YQ = 1000 + 4.3614x - 0.0029x^2$.

The regression analysis revealed that when the plants were rain-fed, grain yield was optimum (1,700 kg ha^{-1}) when 900 kg NPK ha^{-1} was applied while when it was irrigated, grain yield was optimum (3, 500 kg ha^{-1}) when 750 kg NPK ha^{-1}.

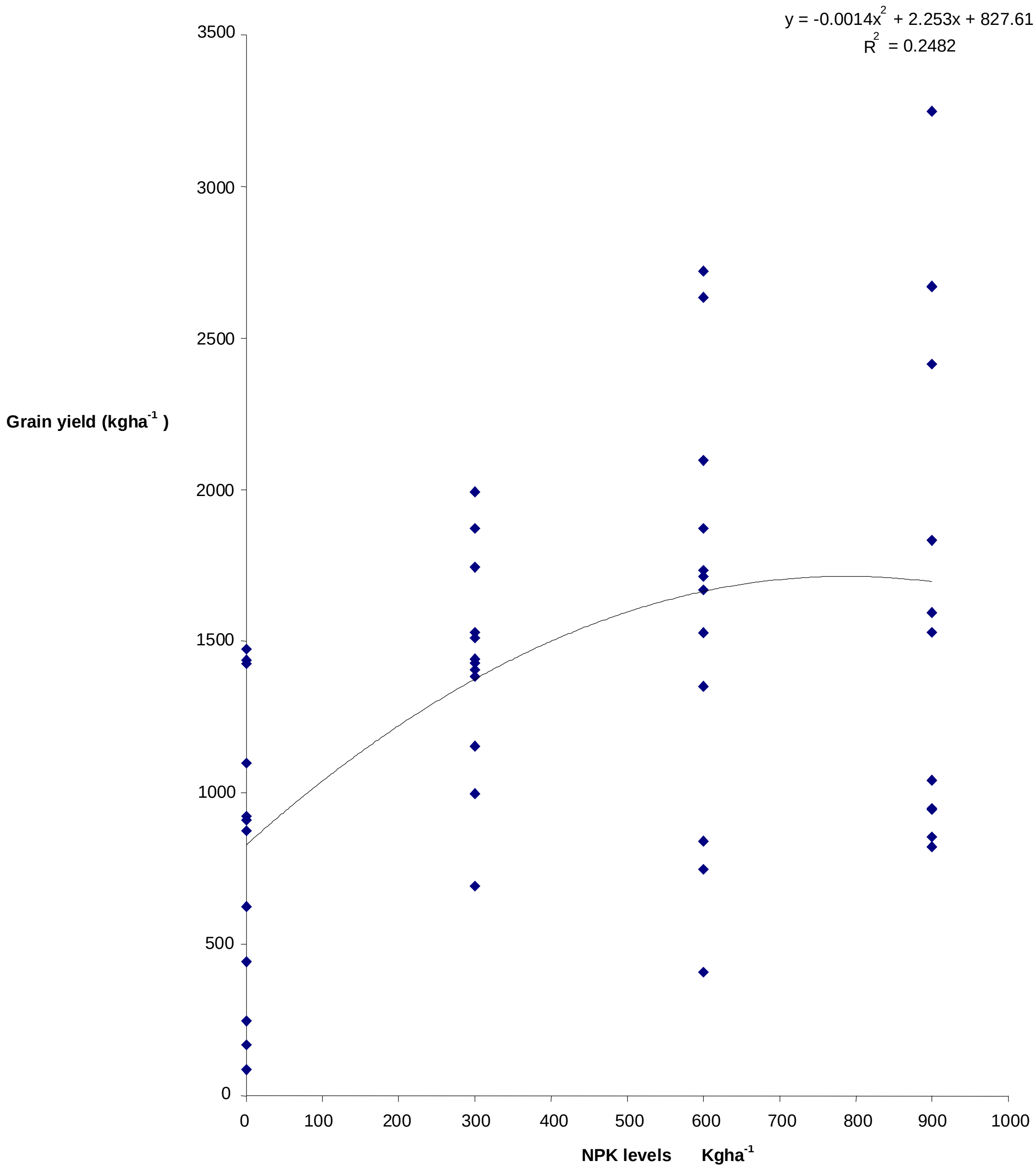

Fig. 1: Regression of grain yield against NPK levels under rain-fed

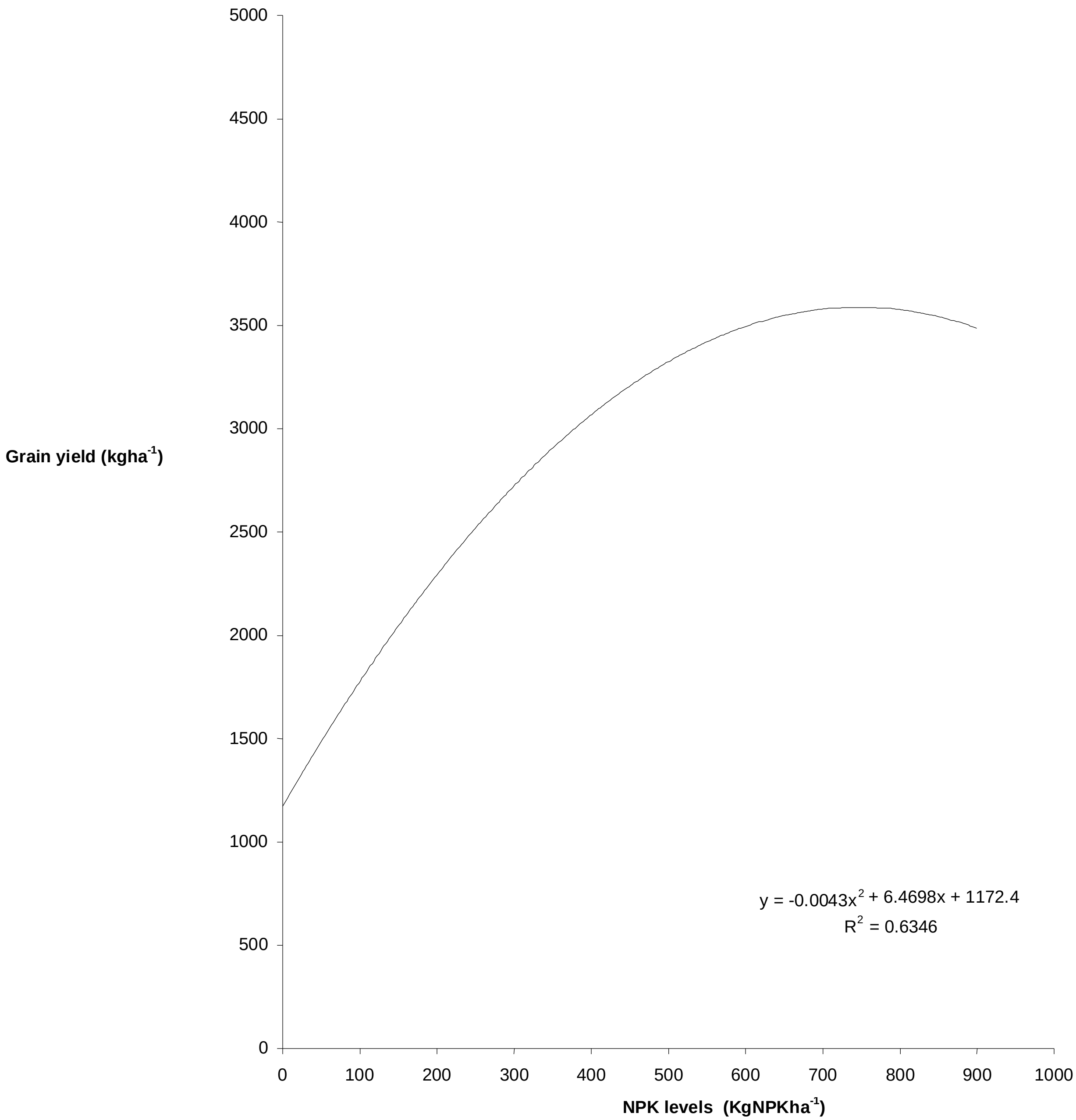

Fig 2: Regression of grain yield against NPK levels under irrigation

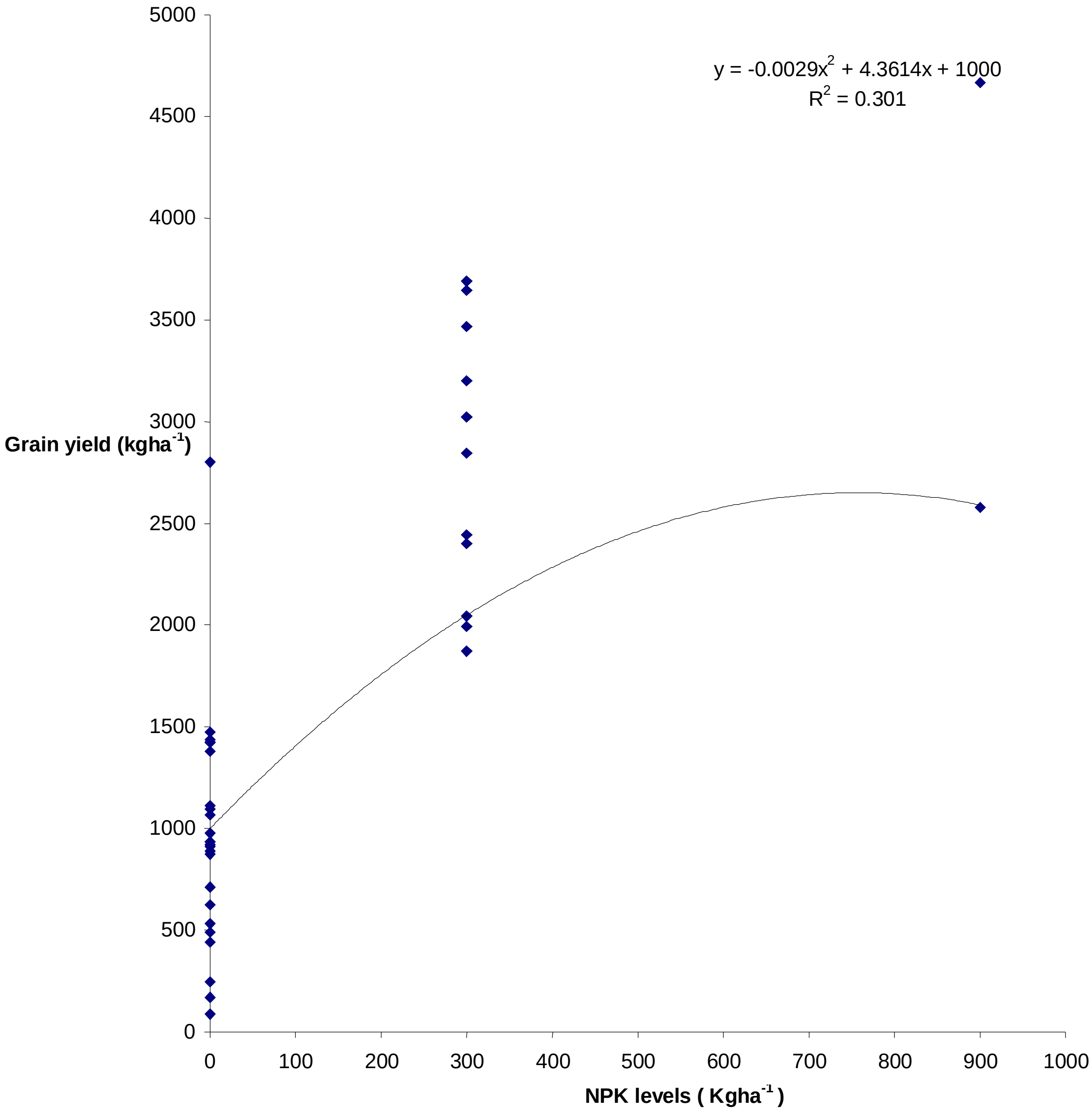

Fig 3- Regression of grain yield against NPK levels for the combined years

Discussion

The significant and positive response of extra-early maize to the application of NPK fertilizer in these trials explained the importance of the nutrients contained in this fertilizer to the yield, and yield components of the crop.

It was observed that increase in fertilizer rate up to 60:30:30kgNPKha^{-1} increased number of cob/plant, and grain yield. This could also be attributed to N.P.K fertilizer being part of the essential nutrients required for the promotion of meristematic and physiological activities such as plant height, number of leaves, plant leaf spread, cob length and grain yield. This is in conformity with the findings of Hassan (1999), and Lawal (2000) who observed increase in 100-grain weight, number of cob/plant and grain yield with increase in fertilizer rates.

The reason for the large difference between the yields under the two water regimes could be that irrigation water can be regulated and may not lead to nutrient being washed away through erosion while natural rain cannot be regulated and may lead to erosion thereby causing loss of nutrient. It could also be that plant under rain-fed could not make efficient use of both the applied nutrient and the native soil nutrient as much as those plants that were irrigated, this may be because some of the applied NPK fertilizer might have diffused in the standing water caused by heavy rain-fall or leached beyond the root zone of the crop. This eventually led to small amount of applied NPK fertilizer available to the crop which may not be enough for vigorous growth, development and high grain yield. This is in conformity with the findings of Nagy, (2000, 2001) where he found out that the effect of fertilization increases with optimal water supply and decreases when harmful water excess is reached.

Another reason that may be attributed to higher yield under irrigation is that maize plants are sun-loving plants that require high temperature for its photosynthetic activities. During the dry seasons, the ideal temperature requirements for maize can be achieved which can lead to higher yield as compared to during the rainy season when the temperature is low and plants are susceptible to different types of diseases and subsequently low yield.

Conclusion

The study therefore revealed that applying NPK fertilizer rate of 180:90:90 kg ha^{-1} and 150:75:75 kg ha^{-1} using NPK 20:10:10 during the raining season and dry season respectively was appropriate in enhancing grain yield of extra-early maize variety 95 TZEE-W in the Sudan Savanna of Nigeria.

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