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# WATER USE EFFICIENCY AND SEED YIELD OF FODDER MAIZE IN RESPONSE TO VARIED PLANTING DENSITY AND NUTRITION UNDER RAINFED SITUATION

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## Abstract

A field study was conducted during *Kharif*-2018 at Indian Grassland and Fodder Research Institute, Jhansi. The study was aimed to determine the water use efficiency and seed yield of fodder maize (African tall) under rainfed condition with different plant populations and graded nutrients levels. Here, three plant populations were taken as main factor and four nutrient levels were considered as sub factor under the set up of split plot design. Results revealed that higher plant population (72,727 $ha^{-1}$) recorded significantly higher seed yield (33.9 q $ha^{-1}$) and water use efficiency (WUE) for seeds (8.45 kg ha-$mm^{-1}$). Similarly, application of N at higher rate plus other major nutrients and Zn (120:60:40:20 kg $N:P_2O_5:K_2O:ZnSO_4$ $ha^{-1}$) produced higher seed yield (38.0 q $ha^{-1}$) and WUE for seeds (9.49 kg ha-$mm^{-1}$). But interestingly the stalk yield of maize did not influence by plant populations and plant nutrition. Further, with respect to interaction, both the plant populations (60,606 and 72,727 pl $ha^{-1}$) and nutrient level (120:60:40:20 kg $N:P_2O_5:K_2O:ZnSO_4$ $ha^{-1}$) produced significantly higher and comparable seed yield and WUE. This increment in seed yield and WUE could be possibly due to the improved plant growth in terms of leaf area, and root activity coupled with yield attributers like 100 seed weight. Since fodder maize is a highly versatile and exhaustive crop, optimum plant population and balanced nutrition are necessary for better utilization of rain water at semi-arid situation to achieve higher and quality seed production.

***Key words*:** Fodder maize, seed yield, plant population, nutrition and water use efficiency.

## Introduction

Livestock is the important subsidiary enterprise in supplementation to the crop husbandry in India. The country has a vast and diverse livestock population and incessantly contributing towards gross value output of the country agriculture. But the concern is about per animal productivity, which is much lower as compared to many developed and developing countries (Halli *et al.*, 2018; Raju, 2013). One of the important reasons behind this is lack of availability of quality fodder (63.5% green and 23.5% dry fodder deficit) with the almost remained stagnant area under fodder cultivation in the country (average 4-5% of the total cropped area). On the other side, the availability of natural resources (water and nutrients) becoming scarce day by day due to climatic vagaries and other reasons (Anon, 2015; Halli *et al*., 2016). However, the critical challenge with us is to improve livestock productivity with existing fodder resources under both the irrigated and rainfed situations through technological intervention.

In this regard, fodder maize has become a major constituent of ruminant rations in recent years, as its inclusion as dairy cow diets improve forage intake, increases animal performance and reduces production costs (Anil *et al.,* 2000). Owing to multiple uses as a food, feed and fodder crop and heavy tonnage maize getting popular in India and replacing other crops area (Halli and Angadi, 2017). So far, all efforts have concentrated on improving vegetative growth and forage nutritive value of the fodder crops and have given little or no attention to seed production. However, in the last few decades, progress has been made in improving crop husbandry and the technique of seed production to get higher seed yield and better quality. In spite of many inventions, the seed yield of fodder maize is low due to complex reasons, among improper usage of nutrients and proper plant geometry is considered one of the major factors, which can increase the production (Aslam *et al.,* 2011). Only through the integration of improved genotypes and crop management practices one can expect higher yield. It is already established that higher grain yield depends on optimum plant density and adequate fertilizer application especially, nitrogen. The application of nitrogen not only affects the forage yield of maize but also improves it is quality and seed yield (Khandakar and Islam 1988). The narrow rows would increase shoot and root dry matter, root length density during early stages because of a decreased plant to plant competition (Ma *et al*., 2003; Sharratt and McWilliams, 2005) and could increase early N absorption. Hargilas (2016) reported that adoption of higher plant density

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with the application of 200 kg N $ha^{-1}$ to winter maize proved to be economical and the seed yield of fodder maize increased significantly up to 150 kg N $ha^{-1}$ (Rupinder, 2013). Therefore, matching the optimum plant density with fertilizer schedule is essential to achieve the higher yields. However, no systematic research has been conducted to optimize the site and need based production technology for this crop, there is a need to find out the association between plant population and nutrients application. In this background, the present study has been planned with the objective of finding the suitable plant population and nutrients application for improved seed yield and WUE.

## Materials and Methods

The field experiment was conducted during *Kharif*-2018 at the Central Research Farm, ICAR-Indian Grassland and Fodder Research Institute, Jhansi (UP). The research station comes under the Semi-arid region with higher temperature and scanty rainfall. The soil type of the experimental site was sandy loam in texture. The soil was normal with respect to pH and electrical conductivity, low to medium in organic carbon content, medium in available nitrogen. The bulk density of top soil (0-30cm) was 1.31g $c^{-3}$. The crop was sown on 11$^{th}$ July 2018 and the total rainfall received during maize growing period varied with respect to amount and intensity (July to October) and was 467.7 mm with 33 rainy days indicates well distribution of rainfall (Fig. 1). The higher amount of rainfall was received during 45-60 DAS (days after sowing) that coincides with the grand growth stage of maize (196.4 mm). The mean maximum temperatures recorded during the crop growth period were highest in the initial stage of the crop (0-15 DAS) the lowest was at the end stage of the crop (105-120 DAS). The average evaporation rate was 4.93 mm $day^{-1}$ during crop duration (Fig. 1). The experiment was laid out in split plot design with three replications comprising twelve treatment combinations with three plant populations in the main plot and four nutrient combinations in subplot. Plant population includes 66,666, 72,727 and 60,606 plants $ha^{-1}$ and four nutrient levels include 100:40:0:0, 80:60:40:0, 100:60:40:20 and 120:60:40:20 kg $N:P_2O_5:K_2O:ZnSO_4$ $ha^{-1}$. The required plant population was maintained through manual sowing with appropriate plant spacing. The gross size of the plot was 20 $m^2$ and the variety grown was African Tall with different spacings (60*25, 55*25 and 55*30 cm). The crop was raised under fully rainfed condition with two shallow protective irrigations (60 mm each) at physiological maturity stage. Whereas, Urea, di-ammonium phosphate (DAP), muriate of potash (MOP) and $ZnSO_4$ were used as sources of NPK and Zn at a defined dosage. Fifty per cent of nitrogen and 100% phosphorus, potassium and $ZnSO_4$ was applied as basal dose and the remaining 50% of N was applied in two splits at 30 DAS and at the tasseling stage. The weed control was done with a pre-emergent application of Atrazine (1.0 kg a.i. $ha^{-1}$) and post-emergent application of topramazone (33.6 g a.i $ha^{-1}$ + adjuvant 2 ml $l^{-1}$ water), also the protective spray was taken against leaf defoliators at seedling stage with profenophos (2 ml $l^{-1}$). The experimental data were analysed by using General Linear Model (PROCGLM) to perform Analysis of Variance (ANOVA) in Statistical Software (var 9.3 SAS). The means separation for each of the variables were performed using LSMEAN procedure ($\alpha = 0.05$).

## Results and Discussion

### Growth parameters

As per the observations, different plant populations influenced the growth parameters (plant height, leaf area, shoot dry weight, root length, number of crown roots and root dry weight) of maize significantly throughout the growth stage. Plant height and leaf area are the main growth attributes decide the photosynthetic ability and final yield of the crop. The combination of plant population (72,727 pl $ha^{-1}$ at 55x25 cm) with 120:60:40 kg $N:P_2O_5:K_2O$+20 $ZnSO_4$ $ha^{-1}$ recorded higher plant height (116.87, 256.22 and 275.77 cm $pl^{-1}$at30, 60 & 90 DAS respectively.) and leaf area as shown in Fig. 2 and 3. However, this treatment combination remained on par with the application of 100:60:40:20 kg $N:P_2O_5:K_2O:ZnSO_4$ $ha^{-1}$ at same plant stand. Whereas, significantly lowest plant height was observed in a population of 60,606 pl $ha^{-1}$ with the application of only 100:40:0:0 kg $N:P_2O_5:K_2O:ZnSo_4$ $ha^{-1}$ (98.40, 240.44 & 248.67 cm $pl^{-1}$ at 30, 60 & 90 DAS respectively). In a similar way, leaf area was also influenced by the combined effect of plant population and nutrients application. Plant population of 72,727 $ha^{-1}$ with 120:60:40 kg $N:P_2O_5:K_2O$+20 kg $ZnSO_4$ per ha recorded higher leaf area (524.4, 659.07 & 662.88 $cm^2$ $pl^{-1}$ at 30, 60 & 90 DAS, respectively). Whereas the lowest leaf area was found in the population of 60,606 pl $ha^{-1}$ with the application of only 100:40:0:0 kg $N:P_2O_5:K_2O:ZnSO_4$ $ha^{-1}$ (432.3, 550.70 & 555.33 $cm^2$ $pl^{-1}$ at 30, 60 & 90 DAS respectively). Similar findings were reported by Suryavanshi *et al*. (2008), higher plant density recorded more leaf area resulted in accumulation of higher dry matter as compared to low plant density. At the population of 72,727 $ha^{-1}$ maize plants might spread their roots laterally as well as vertically led to higher dry weight of maize plants (Table 1). The higher population of 72,727 $ha^{-1}$ with the application of all the major nutrients and Zn contributed to better expression in terms of other growth parameters, mainly total shoot dry weight (112.1 g $pl^{-1}$), root length (28.0 cm $pl^{-1}$), number of crown roots and root dry weight (11.61 g $pl^{-1}$) as given in Table 1. Application of higher levels of nitrogen along with P, K and Zn at optimum population favored the photosynthetic assimilation and greater dry matter. A top dressing of nitrogen in later growth stage showed better translocation of dry matter to the economic portion as reported by Chennakeshava *et al*. (2000) and Aslam *et al*. (2011). The leaf area of crop plant is directly related to the yield of that crop, it improves the rate of photosynthesis that results in more food production by the plant. It shows that higher nitrogen application with all other supplements (P, K & Zn) at optimum plant population produced higher leaf area per plant (20%) over only N application at lower plant population (60,606 pl $ha^{-1}$). The dry matter of plant was also affected significantly by plant populations and nutrients application (Table 1). The maximum dry matter (112.1 g $pl^{-1}$) was produced by 120 kg $ha^{-1}$ with P, K & Zn at plant population of 72,727 $ha^{-1}$, these findings fall in line with the previous observations that narrow rows increased the dry matter accumulation in maize (Cox *et al.*, 2006, Barbieri *et al.*, 2008 and Aslam *et al.*, 2011). The plant spacing of 55 x 25 cm found to be optimum along with 120 kg N $ha^{-1}$ in order to utilize the natural resources like soil moisture, nutrients and sunlight. This has been evidenced through higher shoot as well as root growth (28 cm $pl^{-1}$ length and 11.61 g $pl^{-1}$ dry matter at 30 DAS), which enabled the plant to utilize both above ground as well as below ground resources.

## Yield parameters and water use efficiency (WUE)

Yield and yield parameters and WUE are the result of combined effect of growth parameters attained by the plant. In the present study, the seed yield differed significantly due to plant population and nutrient application (Table 2). Plant population of 72,727 $ha^{-1}$ with 120 kg N $ha^{-1}$ with P, K & Zn produced higher seed yield (39.13 q $ha^{-1}$). The increment in seed yield was about 33.2% over lower plant population of 60,606 $ha^{-1}$ with only N application. However, irrespective of plant population higher N application (120 kg $ha^{-1}$) with P, K and Zn produced higher seed yield. The higher and split application of N might prolong the photosynthetic activity of crop during seed setting and filling stage which in turn influenced both the sink capacity and sink size, led to increased seed yield. The difference in grain yields among plant density and fertility treatments was more associated with total plant dry matter and harvesting index. This was evidenced through increased 100 seed weight (26.48 g) and harvest index (0.42) as per Table 2. Similar findings were reported by Channakeshava *et al*. (2000) and Hargilas (2016). This is proved that increased availability of N at higher levels resulted in the production of better cobs accompanied by increased seed filling. Not only seed filling but also the size of seed was also superior as supported from an increased 100 seed weight. The better grain development in maize might be due to the increased availability of nitrogen and greater production of photosynthates and their efficient translocation for the development of reproductive sinks (Kar *et al.*, 2006). The higher maize yield with closer spacing may be attributed to an increase in the number of plants per unit area which leads to more number of grains per unit area. Since maize is an exhaustive crop needs proper spacing which decides optimum plant population to utilize resources like, sunlight, soil moisture, nutrients, $CO_2$, etc. whereas. The WUE for kernals followed the trend of yield, optimum plant population with proper nutrition better for efficient utilization of soil moisture and was reflected interms of growth and yield parameters. Higher plant poulation at proper nutririon improved the WUE (25-28.5%) over lower plant population with N and P application only as shown in Fig. 4. But interestingly WUE for stalk did not respond to plant population and nutrition, since stalk yield shown less sensitivity as compared to seed yield. Irrespective of population, improved crop nutrition has led to better utilization of soil moisture due to better crop performance (Lie *et al.*, 2007; Ma *et al.*, 2010). Likewise, adoption of higher plant density with application of 150 and 200 kg N $ha^{-1}$ proved to be economical in realizing higher seed yield of maize and the increase in seed yield might be due to production of higher cob length, cob girth and 100 seeds weight (Rupinder, 2013 and Hargilas, 2016). Therefore, matching optimum plant population with optimum fertilizer schedule is essential to achieving the higher yields and moisture harvest. Similarly, Barbieri *et al*. (2008) reported the total dry matter, grain yield and N accumulation in maize was improved with higher nitrogen rate and narrow rows. Hence, exploiting this association between plant population and nutrients application to produce higher seed yields is necessary in order to improve the resource use efficiency (Bhatt, 2012).

In conclusion, maize is an exhaustive and high yielding crop and needs optimum plant stand with balanced nutrition for better seed yield and water use efficiency. Maintaining the plant population of 72,727 $ha^{-1}$ with 120:60:40:20 kg $N:P_2O_5:K_2O:ZnSO_4$ kg $ha^{-1}$ found suitable to produce higher seed yield under rainfed condition. Application of all the major nutrients with zinc is necessary for higher seed yield and water usage of fodder maize.

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**Table 1: Shoot dry weight, root length, root dry weight and number of crown roots of fodder maize as influenced by plant spacing and nutrients application**

| Treatments<br>Spacing (S) | Shoot dry weight (g/plant) | Root length (cm) | Root dry weight (g/plant) | No. of crown roots |
|---|---|---|---|---|
| $S_1$ | 83.52±3.07$^{b}$ | 22.00±0.73$^{ab}$ | 5.8442±0.36$^{b}$ | 23.41±2.59$^{a}$ |
| $S_2$ | 94.096±4.01$^{a}$ | 24.05±0.87$^{a}$ | 8.13±0.79$^{a}$ | 22.58±1.41$^{a}$ |
| $S_3$ | 79.65±3.10$^{b}$ | 20.74±0.73$^{b}$ | 5.65±0.31$^{b}$ | 24.04±2.12$^{a}$ |
| **Nutrients (N)** | | | | |
| $N_1$ | 72.46±2.61$^{d}$ | 20.55±0.92$^{b}$ | 4.54±0.22$^{d}$ | 22.94±0.89$^{a}$ |
| $N_2$ | 80.77±2.71$^{c}$ | 21.34±0.77$^{b}$ | 6.00±0.34$^{c}$ | 23.66±1.06$^{a}$ |
| $N_3$ | 89.32±2.28$^{b}$ | 21.90±0.60$^{b}$ | 7.12±0.60$^{b}$ | 23.88±0.83$^{a}$ |
| $N_4$ | 100.5±3.14$^{a}$ | 25.26±0.94$^{a}$ | 8.49±0.79$^{a}$ | 22.88±1.33$^{a}$ |
| **Interaction (S x N)** | | | | |
| $S_1N_1$ | 70.91±2.46$^{gh}$ | 20.66±2.12$^{b-d}$ | 4.33±0.32$^{ef}$ | 22.00±2.02$^{ab}$ |
| $S_1N_2$ | 79.35±3.11$^{ef}$ | 21.0±1.32$^{b-d}$ | 5.69±0.80$^{c-e}$ | 21.50±2.36$^{ab}$ |
| $S_1N_3$ | 87.76±3.81$^{cd}$ | 22.00±0.86$^{b-d}$ | 6.29±0.27$^{cd}$ | 24.50±1.89$^{a}$ |
| $S_1N_4$ | 96.06±1.58$^{b}$ | 24.33±0.88$^{ab}$ | 7.06±0.27$^{c}$ | 25.66±0.88$^{a}$ |

| | | | | |
|---|---|---|---|---|
| $S_2N_1$ | 79.40±5.78$^{ef}$ | 22.00±1.32$^{b-d}$ | 5.09±0.28$^{d-f}$ | 24.00±1.80$^{ab}$ |
| $S_2N_2$ | 89.12±3.71$^{cd}$ | 22.91±1.26$^{b-d}$ | 6.67±0.48$^{c}$ | 23.66±0.83$^{ab}$ |
| $S_2N_3$ | 95.73±3.37$^{b}$ | 23.28±0.83$^{bc}$ | 9.16±1.10$^{b}$ | 23.66±1.20$^{ab}$ |
| $S_2N_4$ | 112.1±3.38$^{a}$ | 28.00±1.44$^{a}$ | 11.61±0.49$^{a}$ | 19.00±2.08$^{b}$ |
| $S_3N_1$ | 67.06±1.59$^{h}$ | 19.00±1.32$^{d}$ | 4.21±0.46$^{f}$ | 22.83±1.09$^{ab}$ |
| $S_3N_2$ | 73.86±2.35$^{gf}$ | 20.10±1.35$^{cd}$ | 5.65±0.43$^{c-f}$ | 25.83±1.64$^{a}$ |
| $S_3N_3$ | 84.46±1.76$^{de}$ | 20.41±0.96$^{b-d}$ | 5.93±0.08$^{cd}$ | 23.50±1.75$^{ab}$ |
| $S_3N_4$ | 93.23±0.82$^{bc}$ | 23.44±1.38$^{bc}$ | 6.80±0.15$^{c}$ | 24.00±2.08$^{ab}$ |

*$S_1$: 60 x 25 cm (66,666 pl ha$^{-1}$); $S_2$: 55 x 25 cm (72,727 pl ha$^{-1}$); $S_3$: 55 x 30 cm (60,606 pl ha$^{-1}$) and $N_1$: Fodder maize RDF (100:40 kg N:$P_2O_5$ ha$^{-1}$); $N_2$: 80:60:40 kg N:$P_2O_5$:$K_2O$ ha$^{-1}$; $N_3$: 100:60:40 kg N:$P_2O_5$:$K_2O$+20 kg $ZnSO_4$ ha$^{-1}$ & $N_4$: 120:60:40 kg N:$P_2O_5$:$K_2O$+20 kg $ZnSO_4$ ha$^{-1}$.

**Table 2: Seed yield and yield attributers of fodder maize as influenced by plant spacing and nutrients application**

| **Treatments**<br>**Spacing (S)** | **100 seed weight (g)** | **Seed yield (q ha$^{-1}$)** | **Stalk yield (q ha$^{-1}$)** | **Harvest index** |
|---|---|---|---|---|
| $S_1$ | 26.35±0.28$^{a}$ | 32.35±0.85$^{b}$ | 60.88±1.43$^{a}$ | 0.35±0.01$^{b}$ |
| $S_2$ | 25.92±0.23$^{a}$ | 33.91±0.96$^{a}$ | 57.23±2.53$^{a}$ | 0.37±0.01$^{a}$ |
| $S_3$ | 26.25±0.25$^{a}$ | 33.51±1.27$^{ab}$ | 60.78±2.44$^{a}$ | 0.36±0.01$^{ab}$ |
| **Nutrients (N)** | | | | |
| $N_1$ | 25.06±0.26$^{c}$ | 29.74±0.74$^{c}$ | 65.99±3.01$^{a}$ | 0.31±0.01$^{c}$ |
| $N_2$ | 25.99±0.11$^{b}$ | 32.33±0.36$^{b}$ | 62.81±1.44$^{a}$ | 0.34±0.01$^{b}$ |
| $N_3$ | 26.66±0.12$^{a}$ | 32.89±0.39$^{b}$ | 56.95±1.31$^{b}$ | 0.38±0.01$^{a}$ |
| $N_4$ | 26.98±0.41$^{a}$ | 38.06±0.91$^{a}$ | 52.76±1.37$^{b}$ | 0.40±0.01$^{a}$ |
| **Interaction (S x N)** | | | | |
| $S_1N_1$ | 25.06±0.51$^{e}$ | 27.96±1.18$^{d}$ | 62.00±1.77$^{bc}$ | 0.31±0.01$^{gh}$ |
| $S_1N_2$ | 26.16±0.19$^{b-c}$ | 33.0±0.345$^{bc}$ | 65.46±3.01$^{ab}$ | 0.33±0.01$^{e-g}$ |
| $S_1N_3$ | 26.88±0.06$^{ab}$ | 33.40±0.55$^{bc}$ | 57.02±2.38$^{b-d}$ | 0.37±0.01$^{c-e}$ |
| $S_1N_4$ | 27.31±0.12$^{a}$ | 35.01±0.44$^{b}$ | 59.05±2.64$^{b-d}$ | 0.37±0.01$^{b-d}$ |
| $S_2N_1$ | 25.11±0.73$^{e}$ | 31.91±0.58$^{c}$ | 64.78±8.40$^{ab}$ | 0.33±0.03$^{f-g}$ |
| $S_2N_2$ | 25.79±0.20$^{de}$ | 31.96±0.68$^{c}$ | 59.73±2.10$^{b-d}$ | 0.35±0.01$^{d-f}$ |
| $S_2N_3$ | 26.29±0.26$^{b-c}$ | 32.6±0.741$^{c}$ | 50.61±0.74$^{d}$ | 0.39±0.01$^{a-c}$ |
| $S_2N_4$ | 26.48±0.16$^{a-d}$ | 39.13±0.83$^{a}$ | 53.78±2.45$^{cd}$ | 0.42±0.01$^{a}$ |
| $S_3N_1$ | 25.06±0.10$^{e}$ | 29.35±0.91$^{d}$ | 71.18±3.67$^{a}$ | 0.29±0.02$^{h}$ |
| $S_3N_2$ | 26.01±0.18$^{cd}$ | 32.00±0.75$^{c}$ | 63.23±1.75$^{ab}$ | 0.34±0.01$^{d-g}$ |
| $S_3N_3$ | 26.80±0.13$^{a-c}$ | 32.66±0.92$^{c}$ | 50.66±0.92$^{d}$ | 0.39±0.01$^{a-c}$ |
| $S_3N_4$ | 27.16±0.03$^{a}$ | 40.03±1.42$^{a}$ | 58.03±1.42$^{b-d}$ | 0.40±0.01$^{ab}$ |

*$S_1$: 60 x 25 cm (66,666 pl ha$^{-1}$); $S_2$: 55 x 25 cm (72,727 pl ha$^{-1}$); $S_3$: 55 x 30 cm (60,606 pl ha$^{-1}$) and $N_1$: Fodder maize RDF (100:40 kg N:$P_2O_5$ ha$^{-1}$); $N_2$: 80:60:40 kg N:$P_2O_5$:$K_2O$ ha$^{-1}$; $N_3$: 100:60:40 kg N:$P_2O_5$:$K_2O$+20 kg $ZnSO_4$ ha$^{-1}$ & $N_4$: 120:60:40 kg N:$P_2O_5$:$K_2O$+20 kg $ZnSO_4$ ha$^{-1}$.

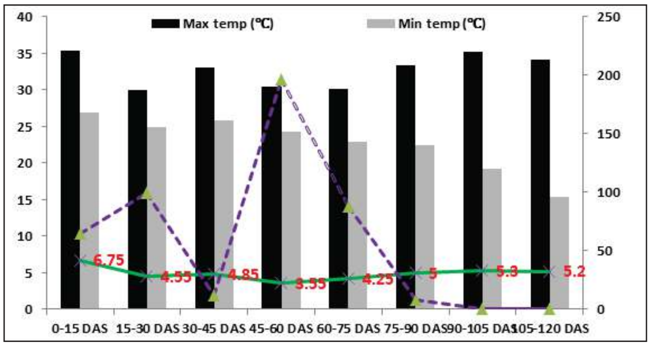



**Fig. 1: Weather parameters of experimental site during cropping period**

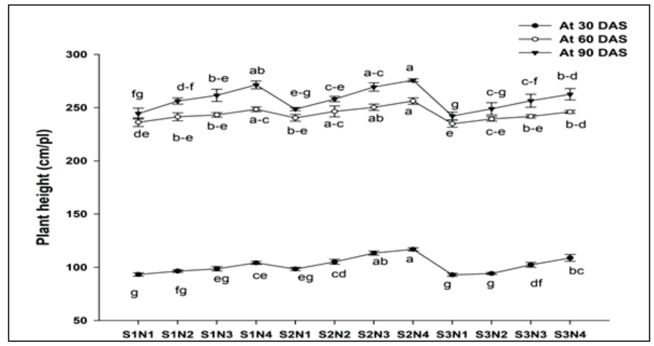



**Fig. 2: Plant height of fodder maize in response to plant spacing and nutrients application**

*$S_1$: 60 x 25 cm (66,666 pl $ha^{-1}$); $S_2$: 55 x 25 cm (72,727 pl $ha^{-1}$); $S_3$: 55 x 30 cm (60,606 pl $ha^{-1}$) and $N_1$: Fodder maize RDF (100:40 kg $N:P_2O_5$ $ha^{-1}$); $N_2$: 80:60:40 kg $N:P_2O_5:K_2O$ $ha^{-1}$; $N_3$: 100:60:40 kg $N:P_2O_5:K_2O$+20 kg $ZnSO_4$ $ha^{-1}$ & $N_4$: 120:60:40 kg $N:P_2O_5:K_2O$+20 kg $ZnSO_4$ $ha^{-1}$.

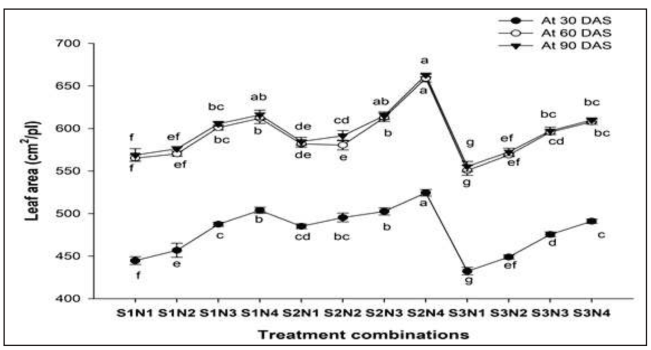
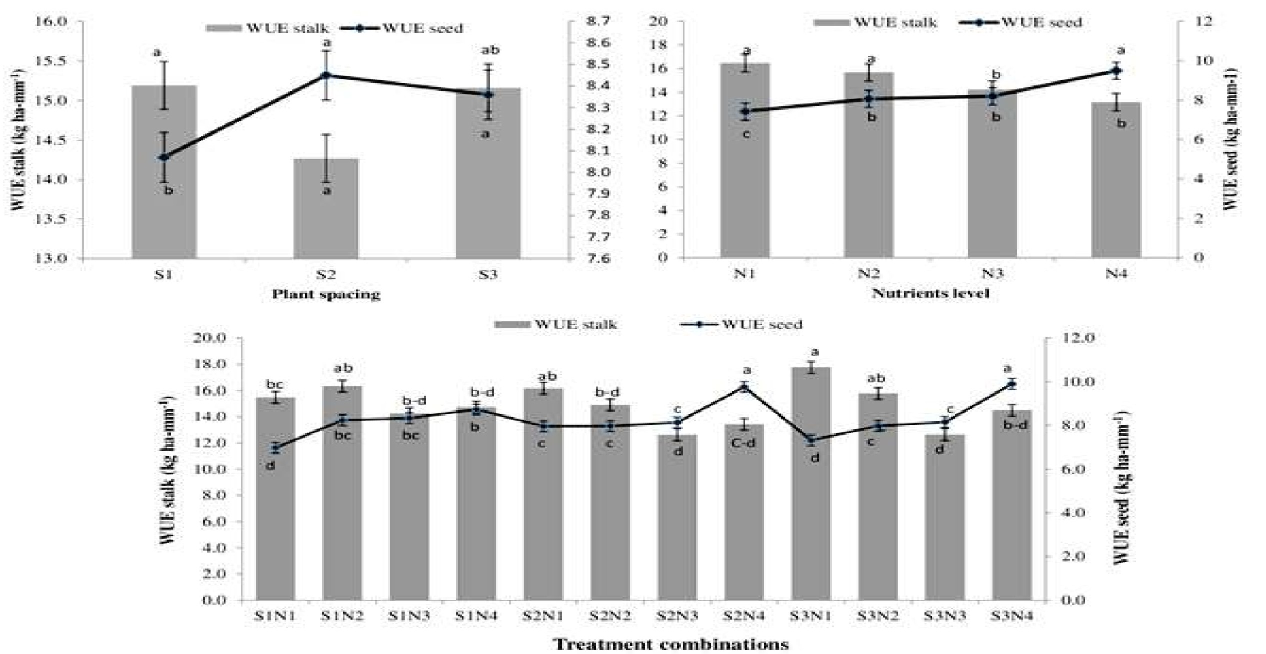



**Fig. 3: Leaf area of fodder maize in response to plant spacing and nutrients application**




*$S_1$: 60 x 25 cm (66,666 pl $ha^{-1}$); $S_2$: 55 x 25 cm (72,727 pl $ha^{-1}$); $S_3$: 55 x 30 cm (60,606 pl $ha^{-1}$) and $N_1$: Fodder maize RDF (100:40 kg $N:P_2O_5$ $ha^{-1}$); $N_2$: 80:60:40 kg $N:P_2O_5:K_2O$ $ha^{-1}$; $N_3$: 100:60:40 kg $N:P_2O_5:K_2O$+20 kg $ZnSO_4$ $ha^{-1}$ & $N_4$: 120:60:40 kg $N:P_2O_5:K_2O$+20 kg $ZnSO_4$ $ha^{-1}$.

**Fig. 4: Water use efficiency of fodder maize in response to plant spacing and nutrients application**