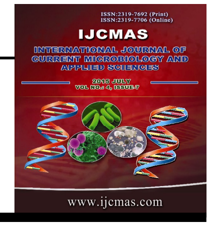
Int.J.Curr.Microbiol.App.Sci (2015) 4(7): 632-639

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 4 Number 7 (2015) pp. 632-639**
http://www.ijcmas.com



Original Research Article

Resource use efficiency of Kharif Maize under Varied Plant Densities and Nitrogen Levels in Telangana State, India

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A B S T R A C T

Keywords

Maize, Plant populations, Nitrogen levels, PAR, RUE, Nitrogen uptake

Field investigation carried out during *kharif* 2013 in college farm, Professor Jayashanar telangana state Agricultural University Rajendranagar, at Hyderabad. Soil of experimental field was sandy loam in texture neutral in reaction (pH 7.4), free from salts (EC 0.28 dSm^{-1}), low in organic carbon (0.4%), nitrogen (175 kg ha^{-1}), Olsen s available phosphorus (36 kg ha^{-1}) and rich in potassium (342 kg ha^{-1}). The study was comprised of 3 levels of plant populations (66,666, 88,888 and 1,11,111 plants ha^{-1}) and 4 levels of nitrogen (120, 180, 240 and 300 kg ha^{-1}). The study revealed that plant population of 1,11,111 plants ha^{-1} recorded higher PAR and RUE. Whereas, significantly higher nitrogen uptake (2.21 g plant^{-1}) was observed with 66,666 plants ha^{-1}.Among nitrogen levels application of 300 kg N ha^{-1} recorded higher PAR and RUE. Significantly higher nitrogen uptake was found with application of 240 kg N ha^{-1}. However, it is comparable with 300 kg N ha^{-1}.

Introduction

Maize (*Zea mays* L) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions and successful cultivation in diverse seasons and ecologies for various purposes. Globally, maize is known as “Queen” of cereals because it has the highest genetic yield potential among the cereals.

In modern maize production systems, enhanced plant-to-plant variability often results from increased competition among individual plants at progressively higher plant densities for limiting resources such as N, incident photosynthetically active radiation (IPAR) and soil moisture. Past studies have often emphasized that stand uniformity is essential for high productivity levels, and that the increased plant-to-plant variability (determined and expressed using a variety of maize growth and developmental parameters) reduces per-unit-area maize grain yields through reduced stress tolerance (Rao *et al.*, 2014). Therefore, at higher plant populations, resource availability must be adequate to help maintain uniform growth, development and grain yield of adjacent plants in a maize canopy.

Maize responds more favourably to plant densities because of higher LAI (leaf area index) at silking, which results in more interception of photosynthetically active radiation and have higher radiation use efficiency during grain filling. The yield potential of maize can be realised only when if it is grown with adequate fertilization and optimum plant population (Singh and Singh, 2006). The relationship between plant dry matter and radiation intercepted has been termed as the radiation use efficiency (Monteith, 1977). Crop photosynthetic rates and RUE is influenced by leaf nitrogen (g N m^{-2} leaf area), when water is not limiting factor (Sinclair and Horie, 1989).

The first prerequisite for high yields is a high production of total dry matter (TDM) per unit area that can be attained through optimizing the assimilate area i.e. LAI to enhance the interception of photosynthetically active radiation (IPAR) and improving the radiation use efficiency. Nutrient uptake by plants is dynamic in nature and is greatly affected by different factors. It is a function of climate, soil properties, amount and method of fertilizer application and cultural practices adopted.

Keeping the above points in view the present study was conducted to better understand the resource use efficiencies particularly of solar radiation and nitrogen.

Material and Methods

The field experiment was conducted at College farm, Rajendranagar, Hyderabad having $17^{0}19'$ N Latitude, $78^{0}23'$ E Longitude and 542.3 m above mean sea level. The experiment was laid out in randomized block design (factorial) with three plant densities (66,666 plants ha^{-1}, 88,888 plants ha^{-1}, 1,11,111 plants ha^{-1}) as one factor and four nitrogen levels (N_1 : 120 kg ha^{-1}, N_2: 180 kg ha^{-1}, N_3 : 240 kg $ha^{-1}$and N_4: 300 kg ha^{-1}) as another factor, replicated thrice. The soil of the experimental site was sandy loam in texture, neutral in reaction (P^H 7.4), low in available nitrogen (175 kg ha^{-1}), high in available phosphorus (36 kg ha^{-1}) and potassium (342 kg ha^{-1}). The other package of practices used recommended for raising the crop.

Intercepted PAR (Photo synthetically active radiation)

Sun scan Plant Canopy Analyser was used to measure the incident and transmitted PAR through canopies during crop growth period at six leaf, silking, dough and physiological maturity stages. The intercepted PAR and transmitted PAR were expressed as percentage.

Radiation use efficiency (RUE)

The radiation use efficiency was calculated as the ratio of dry matter to radiant energy intercepted (Intercepted photosynthetically active radiation) by the crop (Gallagher and Biscoe, 1978).

$$\text{RUE} = \frac{\text{Amount of dry matter produced (g m}^{-2}\text{)}}{\text{Amount of cumulative intercepted PAR (MJ m}^{-2}\text{)}}$$

Nitrogen uptake (kg ha^{-1})

Total N uptake was determined by the following formulae

$$\text{Nitrogen uptake by grain (kg ha}^{-1}\text{)} = \frac{\text{\% N in grain} \times \text{grain yield (kg ha}^{-1}\text{)}}{100}$$

Nitrogen uptake by stover (kg ha^{-1}) =

$$\frac{\%\ \text{N in stover} \times \text{straw yield (kg ha}^{-1})}{100}$$

Data on nitrogen uptake was subjected to analysis of variance procedures as outlined for randomized block design, factorial concept (Gomez and Gomez, 1984). Statistical significance was tested by F–value at 0.05 level of probability and critical difference was worked out where ever the effects were significant.

Results and Discussion

Intercepted of Photosynthetically active radiation (%)

Light intercepted values steadily increased and reached maximum at silking stage and thereafter, interception decreased as the crop proceeds towards physiological maturity (Table 1). Per cent light interception increased with increasing planting density from 66,666 to 1, 11,111 plants ha^{-1} at six leaf, silking, dough and physiological maturity stages (Fig. 1). The increased radiation interception might be due to improved canopy enlargement and number of plants per unit area, even though there was a reduction in leaf area and dry matter per plant (Banerjee and singh, 2003).

Per cent light interception increased with increasing nitrogen levels at all the crop growth stages. Light interception was higher with N_4 (300 kg N ha^{-1}) at six leaf, silking and physiological maturity stages, respectively followed by N_3 (240 kg ha^{-1}), N_2 (180 kg ha^{-1}) and N_1 (120 kg ha^{-1}) (Fig. 2). The radiation interception is primarily determined by the LAI. Nitrogen, being major nutrients of the crop growth, has shown an expansion in the crop leaf surface area (Asim *et al.*, 2012).

Radiation use efficiency (g MJ^{-1})

As the crop age progressed, the RUE increased**.** Highest RUE was observed with 1,11,111 plants ha^{-1} at six leaf, silking, dough and physiological maturity stages respectively and was followed by 88,888 plants ha^{-1}, whereas the lowest values were noticed in 66,666 plants ha^{-1} (Table 2). Increased LAI provide more effective light interception (Tollenaar *et al.*, 1997). In turn, the increased plant density increased the total dry matter production due to greater amounts of solar radiation intercepted (Sinclair, 1998).

The highest RUE was observed with N_4 (300 kg ha^{-1}) and was followed by N_3 (240 kg ha^{-1}), N_2 (180 kg ha^{-1}) and N_1 (120 kg ha^{-1}) (Fig. 3). Increased radiation use efficiency with increased levels of nitrogen might be due to increased leaf emergence speed, leaf area index, leaf area duration, light interception and there by increased yield per unit area (Tohidi *et al.*, 2012). The current result was in line with the result of Watiki *et al.* (1993) who reported RUE of 1.5-1.7 g MJ^{-1} in maize with the application of 80 kg N ha^{-1} in Australia.

Nitrogen uptake (g plant^{-1})

Nutrient uptake is the function of nutrient concentration in plant parts and dry matter yield of the crop. Maximum nitrogen uptake by individual plant at silking and physiological maturity (leaf, stem and grain) was observed in 66,666 plants ha^{-1} and was significantly superior to 88,888 plants ha^{-1} and 1,11,111 plants ha^{-1}. The highest nitrogen uptake was observed at silking and physiological maturity stages (leaf, stem and grain) with 300 kg N ha^{-1} and was followed by 240 kg N ha^{-1} but significantly superior to 180 kg N ha^{-1}) and 120 kg N ha^{-1}(Table 3). Grain received highest portion of nitrogen uptake by plant among leaf, stem and grain. This was mainly attributed to proportionate increase in dry matter production and increase in total biological yield (grain + stover yield) which ultimately increased the total uptake of nitrogen. This result was in conformity with the findings of Kumar *et al.* (2007) and Rani *et al.* (2013).

In conclusion, Optimum plant density for higher resource use efficiencies particularly of solar radiation and nitrogen would be 88,888 plants ha^{-1} and application of 240 kg N ha^{-1}.

Table.1 Intercepted PAR (%) of maize at different growth stages as influenced by plant densities and nitrogen levels

Treatments	Six leaf	Silking	Dough	Physiological maturity
Plant densities (PD) (plants ha^{-1})				
S_1 (66,666 plants ha^{-1})	40.00	83.25	83.00	74.25
S_2 (88,888 plants ha^{-1})	44.10	89.00	86.75	77.50
S_3 (1,11,111 plants ha^{-1})	47.25	92.50	89.50	79.00
Nittrogen (N) Kg ha^{-1}				
N_1 (120 kg ha^{-1})	38.77	84.00	82.66	73.66
N_2 (180 kg ha^{-1})	42.36	86.33	86.00	76.66
N_3 (240 kg ha^{-1})	46.33	90.33	87.66	78.33
N_4 (300 kg ha^{-1})	47.66	92.33	89.33	79.00

Table.2 Radiation use efficiency (g MJ-1) of maize at different growth stages as influenced by plant densities and nitrogen levels

Treatments	Six leaf	Silking	Dough	Physiological maturity
Plant densities (PD) (plants ha^{-1})				
S_1 (66,666 plants ha^{-1})	0.66	1.46	1.19	1.35
S_2 (88,888 plants ha^{-1})	0.76	1.67	1.37	1.54
S_3 (1,11,111 plants ha^{-1})	0.83	1.95	1.59	1.77
Nitrogen (N) (kg ha^{-1})				
N_1 (120 kg ha^{-1})	0.76	1.51	1.30	1.39
N_2 (180 kg ha^{-1})	0.75	1.61	1.35	1.48
N_3 (240 kg ha^{-1})	0.74	1.83	1.43	1.64
N_4 (300 kg ha^{-1})	0.74	1.83	1.44	1.70

Table.3 Nitrogen uptake (g plant-1) by maize at different growth stages as influenced by plant densities and nitrogen levels

Treatment	Silking	Physiological maturity			
		Leaf	Stem	Grain	Total
Plant density (PD) (Plants ha^{-1})					
S_1 (66,666 plants ha^{-1})	0.52^{a}	0.22^{a}	0.13^{a}	1.40^{a}	2.21^{a}
S_2 (88,888 plants ha^{-1})	0.48^{b}	0.19^{b}	0.11^{b}	1.15^{b}	1.86^{b}
S_3 (1,11,111 plants ha^{-1})	0.46^{b}	0.18^{b}	0.11^{b}	1.03^{b}	1.69^{b}
SEm±	0.01	0.01	0.005	0.05	0.06
CD (p=0.05)	0.03	0.03	0.01	0.15	0.18
Nitrogen (N) (Kg ha^{-1})					
N_1 (120 kg ha^{-1})	0.35^{c}	0.14^{c}	0.07^{c}	0.83^{c}	1.41^{c}
N_2 (180 kg ha^{-1})	0.44^{b}	0.17^{b}	0.10^{b}	1.03^{b}	1.65^{b}
N_3 (240 kg ha^{-1})	0.55^{a}	0.23^{a}	0.15^{a}	1.41^{a}	2.24^{a}
N_4 (300 kg ha^{-1})	0.59^{a}	0.25^{a}	0.16^{a}	1.50^{a}	2.36^{a}
SEm±	0.01	0.01	0.006	0.06	0.07
CD (p=0.05)	0.04	0.04	0.01	0.17	0.21
Interaction (PDxN)					
SEm±	0.02	0.02	0.01	0.09	0.12
CD (p=0.05)	NS	NS	NS	NS	NS

Note: Means with same letter are not significantly different

Figure.1 Per cent intercepted PAR at different phenophases of maize at different plant densities

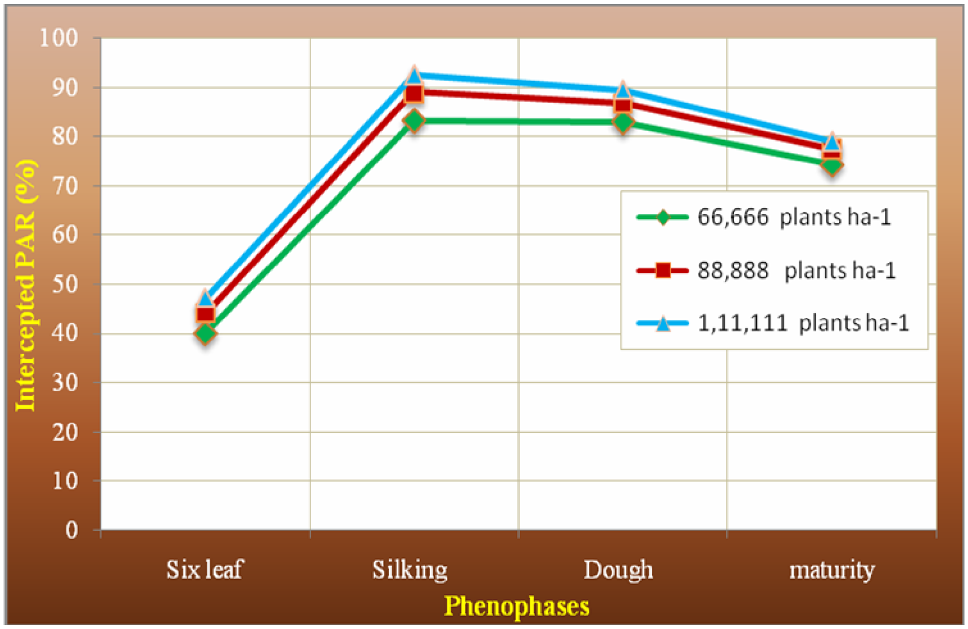


Figure.2 Per cent intercepted PAR at different phenophases of maize under varied nitrogen levels

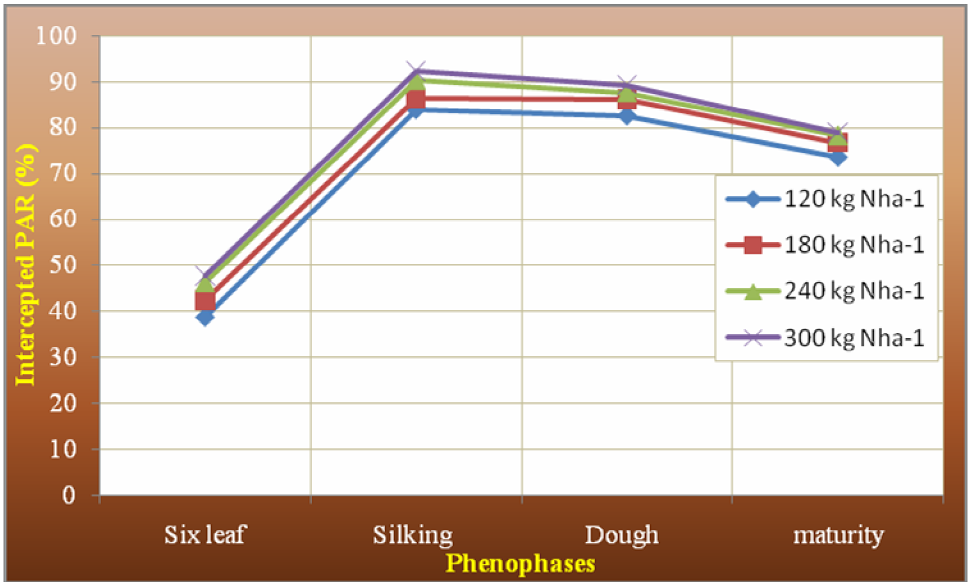
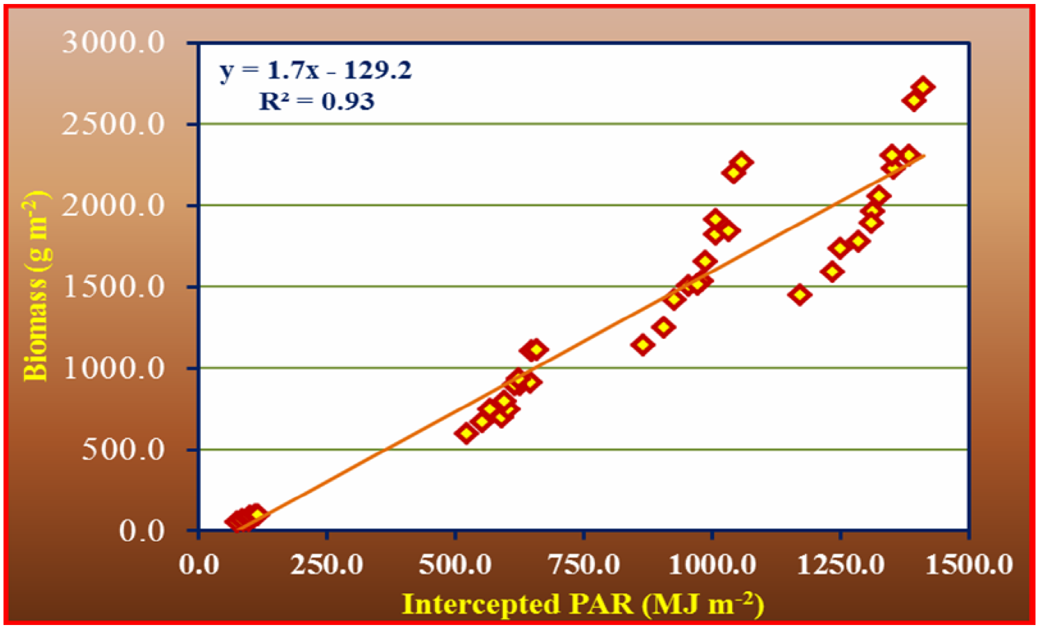


Figure.3 Relationship between intercepted PAR and biomass of maize at different plant densities and nitrogen levels



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