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Abiotic factors (nitrogen and water) in maize : A review

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ABSTRACT

Maize (*Zea mays* L.) is one of the most versatile cereal crops having wider adaptability under varied agro-climatic conditions. Nitrogen and water are the main abiotic factors that limit the yield of maize worldwide. The formulation of nitrogen and water management practices is needed to ensure food productivity for the increasing world population and to address the growing concerns regarding the adverse environmental impacts of agricultural activities. Hence, considering the overall performance in terms of growth, yield and economic returns, it is concluded that with 250 kg N ha^{-1} and irrigation at 0.80 IW/CPE ratio can be recommended under irrigated condition to get higher productivity and benefit cost ratio of maize. In future need to studies that distinguish between biotic and abiotic stress in maize involving spectral remote sensing for vital information required both for the quantification of consequences on production and for taking action for their mitigation.

Key words: Maize, Nitrogen, Stress, Water, Yield.

INTRODUCTION

Maize is one of the most important cereal crops of the world and contributes to food security in most of the developing countries. In India, maize is emerging as third most important crop after rice and wheat. Its importance lies in the fact that it is not only used for human food and animal feed but at the same time it is also widely used for corn starch industry, corn oil production, baby corns *etc*. Among the various inputs, water and fertilizer (nutrients) are considered as the two key inputs making maximum contribution to maize productivity. Out of the three macro elements (NPK), application of nitrogen fertilizer brings out highest yield increase in maize (Szeles *et al*., 2012).

Nitrgen maize

Nitrogen on growth of maize: Rehman *et al.* (2010) reported that plant height was an important yield component. The cultivation of maize with full dose of nitrogen (250 kg ha^{-1}) showed maximum plant height (216.5 cm) and the minimum plant height was recorded in maize with no fertilizer (184.5 cm). Bharathi (2010) reported from Guntur (AP) that significantly higher plant height and dry matter production were observed in maize with the application of 225 kg N ha^{-1} on clay soils.

Results of a study conducted with six nitrogen levels (0, 40, 80, 120, 160 and 200 kg N ha^{-1}) revealed that ear diameter, ear dry matter and ear weight of maize increased with increasing nitrogen level. The periodic data illustrated that rate of N application had highly significant effect on LAI. Maximum LAI (5.06) was observed with 250 kg N ha^{-1}. The decline in LAI was much prominent in lower doses of nitrogen. The maximum TDM (1595 g m^{-2}) at final harvest was accumulated by 300 kg N ha^{-1} followed by 250 kg N ha^{-1} which recorded 1542 g m^{-2}. The minimum value (1403 g m^{-2}) of TDM was observed with 150 kg N ha^{-1} (Hammad *et al.*, 2011b).

By increasing N levels, significant enhancement occurred in LAI and this increased steadily from 20 DAS to 62 DAS for the entire N levels. Maximum values of LAI (4.80) at 62 DAS was in 250 kg N ha^{-1} while minimum 4.19 was observed in150 kg N ha^{-1}. The level of N supply influenced LAI and chlorophyll content of maize (Majnooni-Heris *et al.*, 2011).

Asif *et al.* (2013) reported that maximum plant height of 231.8 cm was recorded in maize plots where nitrogen was applied @ 300 kg ha^{-1} and minimum of 92.5 cm was observed with zero N. Nitrogen levels had also positive correlation with the increment in proline content (Soltani *et al.*, 2013). Singh *et al.* (2014) reported that dry matter plant^{-1}, plant height, LAI, protein content, protein yield and protein productivity were higher under higher levels of nitrogen (160 kg N ha^{-1}) in maize.

Ramachandiran (2015) reported that the nitrogen levels 125 per cent RDN (312.5 kg N ha^{-1}) recorded the highest values for crop growth parameters *viz.*, plant height, LAI, SPAD, chlorophyll content, RWC and DMP. The stress caused by reduction in N levels reduced the maize growth parameters. Significantly higher proline accumulation was observed under nitrogen stressed environment. Higher nitrogen level of 125 per cent of RDN recorded significantly lower proline content of maize.

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Leaf gas exchange parameters: Hammad *et al.* (2012) reported that the effect of the N was in both the vegetative and the reproductive stages of maize, a decline in transpiration occurred with reduced application of nitrogen. Application @ 225 kg ha^{-1} resulted in maximum values for photosynthesis (26.9 μ mol m^{-2} s^{-1}) and transpiration (5.23 m mol m^{-2} s^{-1}). Higher photosynthesis and transpiration rates were recorded in the vegetative stage than in the reproductive stage due to a severe reduction in LAI after silking.

Kolari *et al.* (2014) reported that lesser amount of nitrogen decreased the photosynthetic rate per unit of leaf area which resulted in a reduction in total dry matter accumulation of maize. Application of 125 per cent of RDN (312 kg N ha^{-1}) recorded higher photosynthesis rate (A_n), stomatal conductance (g_s), transpiration rate (T) and intercellular CO_2 concentration (C_i) were observed on maize. Under no nitrogen resulted in lower leaf gas exchange parameters reported by Ramachandiran (2015).

Nitrogen on yield attributes of maize: The minimum cob length (14.4 cm), number of rows cob^{-1} (9.50), number of grain rows cob^{-1} (9.50), grain weight cob^{-1} (44.5 g) and 1000-grain weight (247.3 g) were recorded when no organic and inorganic fertilizers (control) were applied (Cheema *et al.* 2010). The maximum ear length (17.3 cm), number of grains ear^{-1} (692) and 1000 grain weight (302 g) were recorded in maize with full dose of nitrogen 250 kg ha^{-1}. The minimum plant height (10.3 cm), number of grains ear^{-1} (386) and 1000 grain weight (220 g) were recorded in maize with no fertilizer applied (Rehman *et al.*, 2010).

Mukhtar *et al.* (2011) found that N and P applied @ 250 and 125 kg respectively resulted maximum 1000 grain weight (430 g), grain number (658 ear^{-1}), grain weight ear^{-1} (281 g) and grain yield (8.24 t ha^{-1}) followed by N and P application @ 300 and 150 kg, respectively. The highest level of N and P (400 and 200 kg) application declined all these parameters except plant height which attained maximum value (230 cm). Hammad *et al.* (2011a) reported that maximum number of grains cob^{-1} (421), 1000 grain weight (317 g) and maximum harvest index (50.5 per cent) were recorded in the treatment received 250 kg N ha^{-1}. While minimum number of grains cob^{-1} (305), the lowest 1000 grain weight (218 g) and harvest index (30.2 per cent) were observed from the treatment which received no nitrogenous fertilizer.

Maximum (471) numbers of grains per cob was observed with nitrogen @ 250 kg ha^{-1} while further increase in nitrogen supply @ 300 kg N ha^{-1} decreased number of grains cob^{-1}. Maximum 1000-grain weight (352 g) was attained in 200 kg N ha^{-1}. Minimum (439) grains per cob^{-1} and 1000-grain weight (327 g) were obtained by the treatment received 150 kg N ha^{-1} (Hammad *et al.*, 2011c). Whereas, Hammad *et al.* (2012) reported that the highest number of grains per cob and 1000-grain weight was recorded in the 225 kg N ha^{-1} treatments. The treatment without N fertilizer recorded the lowest number of grains per cob and 1000 grain weight.

Asif *et al.* (2013) recorded maximum number of grains cob^{-1} (515.0) and 1000-grain weight (301.7 g) in plots where nitrogen was applied @ 300 kg ha^{-1} against minimum grains cob^{-1} (471) and minimum 1000-grain weight (263.7 g) from zero N. Decline in resources availability at low fertilization might have adversely affected the efficiency of plants to convert intercepted radiation into grain sink capacity as competition for photosynthates causes kernel abortion in maize and less fertilization probably disturbed the source and sink relationship.

Ramachandiran (2015) reported that the yield attributing characters of maize such as cob length (cm), cob girth (cm), number of grains rows cob^{-1}, number of grains row^{-1}, cob weight (g) and 100 grain weight (g) were higher under 100 per cent of recommended dose of nitrogen (250 kg N ha^{-1}) treatment and a reduction in value for yield attributes was observed with no nitrogen application.

Nitrogen on grain yield of maize: The lowest grain yield of maize was recorded from plot where there was no use of organic and inorganic fertilizers (Cheema *et al.*, 2010). The maximum grain yield (6.71 t ha^{-1}) was recorded in maize with full dose of nitrogen 250 kg ha^{-1}. The minimum grain yield of maize (2.69 t ha^{-1}) was recorded with no fertilizer application maize plot (Rehman *et al.*, 2010).

Hammad *et al.* (2011a) reported that grain yield was continuously increased by increasing N rate up to 250 kg N ha^{-1} (8.38 t ha^{-1}). There after grain yield did not respond to further increase of N rates (300 kg N ha^{-1}) implying that increasing the rate of N fertilizer is not a sound strategy for obtaining maximum grain yield. The lowest grain yield (3.93 t ha^{-1}) was recorded from the control treatment.

The maximum grain yield and harvest index (HI) (42.7 per cent) increased with increase in nitrogen rate up to 250 kg ha^{-1} after that it decreased by increasing nitrogen rate at 300 kg N ha^{-1} (N_4) but at that level the total dry matter increased. Sekar *et al.* (2012) revealed that among fertilizer levels, application of 250:125:125 NPK kg ha^{-1} recorded better yield. However, the yield was comparable with 200:100:100 NPK kg ha^{-1}. The grain and straw yields were statistically similar at N application rate of 200 and 300 kg ha^{-1} however they were statistically lower at N application rates of 0 and 100 kg ha^{-1} (Tafteh and Sepaskhah, 2012).

Hammad *et al.* (2012) reported that the highest grain yield (8.40 t ha^{-1}) was recorded in the 225 kg N ha^{-1} treatment. Asif *et al.* (2013) reported maximum grain yield (7.1 t ha^{-1}) with 300 kg N ha^{-1}. Minimum grain yield (4.1 t ha^{-1}) was noted where no N was used. Kolari *et al.* (2014) reported that yield enhanced by nitrogen was due to higher amount of 100 kernel weight and kernel ear^{-1}.

The reduction in dry matter and grain yield in nitrogen stress treatment (0 kg ha^{-1}) were 33.7 and 38.7 per cent, respectively as compared to the highest N level (300 kg ha^{-1}) (Azizian and Sepaskhah, 2014). Maize responded positively upto 250 kg N ha^{-1} and recorded the highest grain yield. Grain yield did not respond further to applied nitrogen when the level as increased to 312 kg ha^{-1}. The effect of nitrogen stress was noticeable with reduced grain yields of maize under no nitrogen (N_0) application reported by Ramachandiran (2015).

Nitrogen on stover yield of maize: The maximum biological yield (19.33 t ha^{-1}) was recorded in maize with full dose of nitrogen 250 kg ha^{-1}, while the minimum biological yield (9.3 t ha^{-1}) was recorded with no fertilizer application (Rehman *et al.,* 2010). The positive and significant improvement in LAI and DMP at different stages and higher nutrient uptake due to higher dose of fertilizer resulted in enhanced stover yield (Ananthi *et al.,* 2011).

Biological yield was significantly increased with increasing N level up to 300 kg ha^{-1}. The maximum biological yield (16.9 t ha^{-1}) was produced when N was applied at the rate of 300 kg ha^{-1} and it was statistically similar with treatment receiving 250 kg N ha^{-1}. The lowest biological yield (13.0 t ha^{-1}) was resulted from the treatment with no nitrogen (Hammad *et al.,* 2011c). The increase in dry matter accumulation with higher level of nitrogen was due to better crop growth, which also recorded maximum plant height, LAI and ultimately produced more biological yield (Leelarani *et al.,* 2012).

The maximum green forage yield (47.5 t ha^{-1}) and dry matter yield (10.4 t ha $^{-1}$) were recorded in case of 100 per cent recommended dose of nitrogen. The minimum dry matter yield of forage maize was observed with no application of nitrogen (7.14 t ha^{-1}) (Iqbal *et al.,* 2014). Ramachandiran (2015) reported that there was an appreciable increase in stover yield due to increment in nitrogen levels. Application of 125 per cent of recommended dose of nitrogen (312.5 kg N ha^{-1}) recorded higher stover yield of maize. The lowest stover yield of maize was recorded with no nitrogen application, under nitrogen stressed condition.

Nitrogen on nutrient uptake of maize: Ananthi *et al.* (2010) reported that application of 200:100:100 NPK kg ha^{-1} recorded the highest nitrogen uptake in maize (97.2 kg ha^{-1}). Meena *et al.* (2012) found that significantly higher value of nitrogen uptake by cob, fodder and total uptake by crop and available nitrogen in soil of the harvest of sweet corn were observed with application of 125 per cent RDN. Reddy *et al*. (2012) from Warangal on sandy clay loam soil observed that application of 240 kg N ha^{-1} resulted in significantly higher nitrogen uptake (kernel or stover or total) compared to lower doses of 120 and 180 kg N ha^{-1} under zero tillage conditions in rice fallows.

Water on maize

Maize is negatively affected by many environmental factors during growth with moisture stress being one of the most common causes for reductions in maize yields worldwide (Hassan *et al.,* 2013). Maize, a miracle crop was grown over a wide range of climatic conditions in semi arid and sub-tropics on Indian continent. Besides, it was a water demanding crop; higher grain yields can be achieved when water and nutrients were not limiting (Adamu *et al.,* 2014). Water on growth of maize: Amer (2010) reported that deficit irrigation reduced dry matter production and leaf area index of maize. Parthasarathi (2010) reported that the maximum plant height (130.7 cm), total dry matter production (223.2 g plant^{-1}) and leaf are index (4.77) were recorded in IW/CPE ratio 0.8, The lowest plant height and total dry matter production, LAI, chlorophyll content were recorded by IW/CPE ratio 0.4. Simsek *et al.* (2011) reported that plant height, biomass and shoot water content increased with increased IW/CPE ratio (25 per cent to IW/CPE ratio (1.0 per cent).

Shivakumar *et al.* (2011) reported that maintenance of adequate moisture by irrigation at IW/CPE ratio of 1.0 resulted in significantly higher plant height (155.5 cm) and leaf area index (4.43) and total dry matter (75.6 g plant^{-1}) and green fodder yield (43.5 t ha^{-1}) over rest of the treatments. Delayed irrigations successively up to harvest (0.6 IW/CPE ratio) recorded significantly lower total dry matter production apart from the green fodder yield of corn.

Shah *et al.* (2011) reported that plant height (150.1 cm) at harvest was significantly the highest under IW/CPE ratio of 1.0 as compared to IW/CPE ratio 0.6, which remained at par with 0.8 IW/CPE ratio. The increase in plant height at harvest under 1.0 IW/CPE ratio and 0.8 IW/CPE ratio irrigation levels were 9.88 and 7.47 per cent over irrigation at 0.6 IW/CPE ratio irrigation level, respectively.

Parthasarathi *et al.* (2012b) reported that the maximum Chlorophyll 'a' (0.991), Chlorophyll 'b' (0.312), total chlorophyll content (1.40) and chlorophyll stability index (73.2) were recorded in IW/CPE ratio of 0.8. While the lowest chlorophyll content and CSI were observed at IW/CPE ratio of 0.4. The photosynthetic rate and stomatal conductance values had a gradual decrease with decrease in irrigation levels to IW/CPE ratio 0.4 at all the growth stages. The transpiration rate had a direct link with water content of the crop. A steep decrease in transpiration rate was observed with reduced irrigation level at all the stages of maize.

Increasing severity of water stress clearly reduced the photochemical activity of chlorophyll, absorption of nutrients by corn roots and nutrient transportation from root to shoots (Elmetwalli *et al.,* 2012). Water stress led to significant decrement of chlorophyll content in maize cultivars (Soltani *et al.,* 2013). A decrease in chlorophyll content from water stressed plants provided evidence that water deficiency degraded the photosynthetic pigments and changed the leaf morphology in corn canopies (Genc *et al.*, 2013).

Higher values for plant height (198.8 cm) above ground dry matter accumulation (259.6 g plant^{-1}) and SPAD value (41.3 were observed with irrigation scheduled at IW/ CPE ratio 0.8. The LAI of maize was reduced by 34.9 and 8.3 per cent under water (0.5 I_1) and nitrogen (0 kg ha^{-1}) stress, respectively (Azizian and Sepaskhah, 2014).

Ramachandiran (2015) reported that irrigation scheduled at 0.80 IW/CPE ratio recorded the highest values for crop growth parameters *viz.*, plant height, LAI, SPAD, chlorophyll content, RWC and DMP. Water stressed condition of irrigation at 0.50 IW/CPE ratio recorded significantly the lowest plant growth parameters. Significantly higher proline accumulation was observed under water stressed environment in maize.

Relative water content (RWC): Drought stress could create loss of homeostasis in water status in plants which lead to a decrease in RWC, chlorophyll degradation and photosynthetic disorder (Pinheiro and Chaves, 2010 and Sage and Zhu, 2011). The RWC decreased significantly with increasing moisture stress. IW/CPE ratio 0.8 had higher RWC by about 82.8 per cent. This might have attributed to better availability of soil moisture in the crop root zone (Adamu *et al.*, 2014). Ramachandiran (2015) reported that irrigation scheduled at 0.80 IW/CPE ratio recorded maximum RWC in maize and under water stressed environment (0.50 IW/CPE) RWC was reduced significantly.

Proline content: The imposition of stress increased the proline accumulation at about 62.5 per cent in IW/CPE ratio 0.4 as compared to IW/CPE ratio 0.8, which recorded 93.4 µg g^{-1}.

The reduced level of irrigation water could significantly increase the canopy temperature form 28.1°C in IW/CPE ratio 0.8 and 30.2 °C in IW/CPE ratio 0.4 (Parthasarathi, 2010). Withholding of irrigation at different stages of crop development resulted in an increase of proline content with a decrease in relative water content (Mansouri *et al.*, 2010).

Water deficiency induced significant increase in proline content of maize leaves (Soltani *et al.*, 2013). The imposition of water stressed environment in maize significantly increased proline accumulation about 90.3 µg g^{-1} fl with irrigation at 0.50 IW.CPE ratio. Under normal irrigation (0.80 IW/CPE ratio), proline accumulation was less with value of 50.1 µg g^{-1} fl reported by Ramachandiran (2015).

Leaf Gas Exchange parameters: The photosynthetic rate was significantly reduced by water deficit. Maximum transpiration was recorded in the full irrigation while the lowest transpiration rate was reached in water stress reported by Hammad *et al.* (2012).

In maize as a result of gas exchange photosynthetic rate (A_n) and stomatal conductance (*gs*) were statistically higher in full irrigation treatment as compared to other irrigation levels by an average of 44 and 76 per cent, respectively. Water deficit showed that photosynthetic rate (*An*) stomatal conductance (*gs*) and transpiration rate (*T*) were statistically decreased under water deficit by an average of 30, 43 and 75 per cent as compared to full irrigation, respectively. Lower *An* accompanied by lower *gs* and *Ci* might be mainly ascribed to stomatal closure, which restricted entry of CO_2 into leaves (Azizian and Sepaskhah, 2014).

Irrigation scheduled at 0.80 IW/CPE ratio recorded higher photosynthesis rate (A_n), stomatal conductance (g_s), transpiration rate (*T*) and intercellular CO_2 concentration (C_i) were observed on maize. Under water stressed condition of irrigation at 0.50 IW/CPE ratio resulted in lower leaf gas exchange parameters reported by Ramachandiran (2015).

Water on yield attributes of maize: Maximum numbers of grains (474) cob^{-1} and 1000-grain weight (361 g) were produced with eight irrigations while minimum numbers of grains (441) cob^{-1} and 1000-grain weight (330 g) were obtained when there was stress at vegetative stage. This could be due to stress that affected grain formation (Hammad *et al.*, 2011c). Grain yield is also determined by the number of kernels plant^{-1} and kernel weight during the grain filling period due to more translocation of photo assimilates especially at post silking period which mostly depends on the absorbed photosynthetically active radiation (APAR) and radiation use efficiency (RUE) (Parthasarathi *et al.*, 2012a).

Aulakh *et al*. (2012) reported that irrigation at IW/ CPE ratio 1.25and 1.0 IW/CPE ratio produced 370.4 and 365.4 grains cob^{-1}, respectively. The increase in number of grains cob^{-1} might be due to lower barrenness of the cobs under higher irrigation regimes (IW/CPE ratio 1.25 and 1.00) receiving 3 irrigations during growth period. The reduction in barrenness of cobs at higher irrigation level might be due to better pollination and consequent to better filling of cobs due to optimum moisture availability. The maximum value of test weight (29.8 g), cob length, cob girth and shelling percentage (79.0 per cent) were recorded under IW/CPE ratio of 1.25.

The maximum number of grains ear^{-1}, 1000 grain weight and higher grain yield were obtained by irrigation at 50 mm pan evaporation whereas the lowest number of grains ear^{-1}, 1000 grain weight and higher grain yield were obtained at 200 mm pan evaporation (Tarighaleslami *et al.*, 2012).

Reddy *et al.* (2012) reported that IW/CPE ratio of 1.0 recorded significantly higher plant dry weight at harvest, number of kernels cob^{-1}and kernel weight cob^{-1} in maize crop. Parthasarathi *et al.* (2013) reported that the higher cob girth of 17.1 cm, cob weight (128.8 g), cob kernel weight (100.6 g) and 100 kernel weight (27.5 g) were recorded in normal irrigation of 0.8 IW/CPE and reduced with decreased number of irrigations at IW/CPE ratio of 0.4. Adamu *et al.* (2014) reported that IW/CPE 0.8 was found to be the better irrigation option on account of higher cob length, cob girth, number of grains row^{-1} and 1000 seed weight. The significant increases in these yield components were due to beneficial effect of sufficient moisture available in the soil.

Irrigation scheduled at 0.80 IW/CPE ratio produced significantly higher the yield attributing characters of maize such as cob length (cm), cob girth (cm), number of grains rows cob^{-1}, number of grains row^{-1}, cob weight (g) and 100 grain weight (g). A reduction in value for yield attributes was observed at 0.50 IW/CPE ratio, under water stress environment condition (Ramachandiran, 2015).

Water on grain yield of maize: Maximum maize grain yield was recorded when irrigation was scheduled at IW/CPE ratio of 1.0. Significantly the lowest yield was recorded when the irrigation was scheduled at IW/CPE ratio of 0.6 (Ramulu *et al.*, 2010). Simsek *et al.* (2011) reported that the highest corn yield and silage quality were obtained at the full (IW/CPE ratio 1.0) irrigation regime. The superiority of this could be attributed to the fact that frequent irrigation provides the crop with adequate moisture in the surface layer in which most of the maize roots exist, thus resulting in better crop nourishment and consequently higher yield which was also reported by Elzubeir and Mohamed (2011).

Kernel yield of the crop recorded a maximum value of 5960 kg ha^{-1}in normal irrigation (IW/CPE ratio 0.8). Maize kernel yield was reduced by 25.8 per cent and 45.9 per cent when plants were subjected to water deficits of 75 per cent water requirement (IW/CPE ratio 0.6 I_2) and 50 per cent water requirement (IW/CPE ratio 0.4), respectively, as compared to normal irrigation. The harvest index under normal irrigation was higher (34.3 per cent) than the lowest irrigation water levels (30.8 per cent) (Parthasarathi *et al.*, 2012a).

The grain yield was significantly increased up to IW/CPE ratio 1.0 irrigation level (81.2 q ha^{-1}) as reported by Aulakh *et al.* (2012). Water stress at the vegetative stage reduced the grain yield by 12.2 per cent, whereas the same treatment at the grain filling stage reduced the grain yield by 22.6 per cent as reported by Hammad *et al.* (2012).

Maize grain yield with IW/CPE ratio 1.0 irrigation was significantly higher than IW/CPE ratio 0.8 (Sreelatha *et al.*, 2013). Adamu *et al.* (2014) reported that higher grain yield (81.4 q ha^{-1}) was recorded in irrigation scheduled at 0.8 IW/ CPE ratio followed by irrigation scheduled at critical growth stages of maize (71.7 q ha^{-1}). Dry matter and grain yield statistically increased with increasing water levels and with nitrogen application. Maize produced less dry matter (57.6 per cent) and grain yield (52.3 per cent) at water stress conditions (I_3=0.5 I_1 treatment) compared to the no water stress treatment (I_1=1.25 ETc) (Azizian and Sepaskhah, 2014).

The grain yield was favorably increased under irrigation scheduled at 0.80 IW/CPE ratio, recording significantly the highest grain yield of 5781 kg ha^{-1}. Maize grain yield of 3966 kg ha^{-1} are recorded under water stress with irrigation scheduled at 0.50 IW/CPE ratio reported by Ramachandiran, (2015).

Water on stover yield of maize: Sunder Singh (2001) observed that young cob yield and stover yield were also maximum in IW/CPE ratio of 1.0 (27.9 q ha^{-1}) over others in sandy soil during summer at TNAU. Parthasarathi *et al.* (2012a) reported that maize crop registered a higher biomass production in IW/CPE ratio 0.8 (11428 kg ha^{-1}) than IW/CPE ratio 0.4 (7232 kg ha^{-1}).

The stover yield was significantly increased up to IW/CPE ratio 1.0 irrigation level (150.7 q ha^{-1}) (Aulakh *et al.*, 2012). Significantly higher kernel yield and stover yield was recorded with IW/CPE ratio of 1.0 as reported by Reddy *et al.* (2012). Ramachandiran, (2015) reported that stover yield increased significantly with irrigation at 0.80 IW/CPE ratio. Water stressed condition of irrigation at 0.50 IW/CPE ratio recorded significantly the lowest stover yield.

Nitrogen and water maize

Water and nitrogen are the most important factors which play a major role in better growth and yield of maize (Hammad *et al.*, 2011c). Water and nitrogen are two of the most critical inputs required to achieve the high yield potential of modern corn varieties. Under most agricultural settings, however, they are often scarce and costly. Large gaps remain between our empirical knowledge of the physiological changes observed in the field in response to nitrogen and water stresses (Humbert *et al.*, 2013).

Nitrogen and water on growth of maize: Water use efficiency was the highest for full irrigation (100 per cent SMD) under 225 kg N ha^{-1} treatment, and the lowest for no irrigation and non-fertilized (Abedinpour *et al.*, 2011). Khatun *et al.* (2012) revealed that irrigation and nitrogen significantly influenced the plant height, LAI, total dry matter and crop growth rate. Proline also increased significantly under drought stress conditions showing that osmotic adjustment mechanism had been activated. The highest level of leaf proline (180.2 ì mol g^{-1} NT) was achieved with 200 mm evaporation and 80 kg ha^{-1} of nitrogen fertilizer (Tarighaleslami *et al.*, 2012).

Irrigation scheduled at 0.80 IW/CPE ratio along with 125 per cent of RDN (312 kg ha^{-1}) registered higher plant height, leaf area index, SPAD, chlorophyll content, dry matter production and maximum nutrient uptake of maize. Stressed environment reduce the plant height, LAI SPAD, chlorophyll content and DMP of maize grown with irrigation scheduled at 0.50 IW/CPE ratio without nitrogen application. Under stressed condition reduction in nutrient uptake of maize to the tune of 54.43 to 68.69 per cent in nitrogen, 46.78 to 53.98 per cent in phosphorus and 52.29 to 61.39 per cent in potassium was recorded (Ramachandiran, 2015).

Nitrogen and water on yield attributes and yield of maize: More grains per cob (490) was obtained with eight irrigation and 250 kg N ha^{-1} and maximum number of 1000 grain weight (376 g) was obtained with eight irrigations 200 kg N ha^{-1} while minimum number of grains per cob (427) and minimum 1000 grain weight (314 g) was found in 150 kg N ha^{-1} under vegetative stress (Hammad *et al.*, 2011c).

The maximum and minimum yield of 6050 and 1430 kg ha^{-1} were obtained with full irrigation (100 per cent soil moisture deficit (SMD) with 225 kg N ha^{-1} and rainfed conditions without N application, respectively (Abedinpour *et al.*, 2011). A close relationship between soil moisture and N availability for plant uptake was also reported by Aynehband *et al.* (2011). When crop was normally irrigated with nitrogen dose at the rate of 250 kg ha^{-1}, the highest grain yield and HI were achieved (Hammad *et al.*, 2011c).

Hammad *et al.* (2012) also reported that the highest grain yield (8.40 t ha^{-1} in) was achieved in the full irrigation with 225 kg N ha^{-1} treatments and the lowest grain yield was recorded with water deficit in the reproductive stage without nitrogenous fertilizer treatments. The highest harvest index (46.4 per cent) was also observed for the full irrigation with 225 kg N ha^{-1}. Water and N deficit condition, lead to a reduction in crop production by reduced resource capture and resource use efficiency (Soltani *et al.*, 2013).

Ramachandiran, (2015) indicated that the yield attributing characters and yield of maize were higher under irrigation scheduled at 0.80 IW/CPE ratio along with 100 per cent of recommended dose of nitrogen (250 kg ha^{-1}) treatment. A reduction in value for yield attributes and yield was observed at irrigation scheduled at 0.50 IW/CPE ratio along with no nitrogen application.

Economics: The minimum net return (Rs. 24925) was obtained with no nitrogen fertilizer application in maize plot (Rehman *et al.*, 2010). The trend of B:C ratio indicated that the IW/CPE ratio 0.8 was able to maintain its superiority by registering higher value of 2.2 against the lowest value of 1.43 in IW/CPE ratio 0.4 (Parthasarathi, 2010). The higher net returns were obtained with irrigation at an IW/CPE ratio of 1.0 as reported by Reddy *et al.* (2012). Raskar *et al.* (2013) from Vadodara reported the highest BCR with the application of 160 kg N ha^{-1} than lower levels of N (80 and 120 kg ha^{-1}) on sandy loam soil. Ramachandiran, (2015) reported that The highest gross return of Rs.99641, net return of Rs. 65380 and B:C ratio of 2.91 were recorded higher under the fertilizer dose of 250 kg N ha^{-1} with irrigation at 0.80 IW/CPE ratio.

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