Evaluation of Drought Mitigation Strategy And Irrigation Scheduling To Increase Irrigation Use Efficiency And Grain Yield of Hybrid Maize

Thukkaiyannan P
Agricultural College and Research Institute, Vazhavachanur, Tiruvannamalai (Dt)
Tamilnadu, India

Abstract- *The field experiment was conducted at Maize Research Station, Vagarai during late rabi / early summer period of 2019 and 2020 to evaluate the drought mitigation strategies and irrigation scheduling to increase irrigation use efficiency and grain yield of hybrid maize. The foliar spray of drought mitigation materials coincides with critical stages of maize crop (knee high stage, pre flowering stage and flowering stage). Irrigation scheduling was fixed based on available soil moisture (ASM) at 50 % ASM, 40 % ASM, 30 % ASM and 20 % ASM. A significantly higher plant population (59,220 plants/ha and 59,930 plants/ha) was recorded in control and irrigation given at 50 % available soil moisture respectively at 25 DAS. The plant height was significantly higher (135.2 cm and 142.5 cm respectively) in PPFM (1 %) foliar spray at knee high, pre flowering and flowering stages and irrigation scheduling at 50 % ASM at 50 DAS. The significant higher dry matter was obtained (6,715 kg/ha and 7,522 kg/ha respectively) in foliar spray of PPFM (1 %) at critical stages and irrigation scheduling at 50 % ASM. Grain yield of maize was significantly higher (5,564 kg/ha) in spraying of PPFM (1 %) at critical stages of maize viz., knee high stage, pre flowering and flowering stages. Irrigation given at 50 % ASM gave significantly higher grain yield (8,355 kg/ha) than other irrigation schedules. The crop water use efficiency was higher (13.31) in irrigation scheduling at 50 % ASM. The net returns and benefit cost ratio calculated that the higher net returns and benefit cost ratio of Rs.40,023/ha and 1.65 respectively in spraying of PPFM (1 %) at critical stages and Rs.88,776/ha and 2.44 respectively in irrigation scheduling of 50 % ASM.*

Keywords- Maize, Drought mitigation, Irrigation scheduling, Maize grain yield, PPFM, Water use efficiency.

I. INTRODUCTION

In India, only 4.2 % of the world fresh water resources are available. Agriculture sector in India has been and is likely to remain the major user of water (NCA, 1976). It is estimated that the share of water allocated for irrigation is likely to decrease by 10–15% in near future. The reduction of maize productivity under drought stress conditions depends on different factors such as plant development stage, drought intensity and duration of water deficit, and varietal sensitivity to drought stress (Fiedrick *et.al*., 1989). Water stress decreases relative water contents, water potential, growth and yield of various crops (Akram, 2011). Drought stress is one of the major constraints to agriculture where limited water availability for crop irrigation causes a reduction in carbon fixation by the photosynthetic apparatus that result in net yield losses (Eldakak *et.al.*, 2013).

Potassium is known as a stress alleviator plant nutrient which alleviates the negative consequences of abiotic stresses by regulating the physiological and biochemical process in plants. Aslam *et.al*. reported that potassium improves drought tolerance by improving root growth, cell turgor pressure, and osmotic pressure. Various formulations of potassium are available in the global markets. Among these, muriate of potash (KCl) is commonly used as a source of K. It contains a maximum amount of K2O, however, chloride (Cl_2) in access amounts in KCl inhibits nitrification and affects uptake of nitrogen, potassium, phosphorus, and calcium which may also result in non significant effect of fertilizers on crop performance. Amanullah *et.al.*, (2016) reported that foliar and soil applied potassium improved maize performance under moisture stress.

Pink pigmented facultative methylotrophic bacteria (PPFM) are associated with the roots, leaves and seeds of most terrestrial plants and utilize volatile C1 compounds such as methanol generated by growing plants during cell division (Irvine *et.al.*, 2012). Increasing CO_2 concentration inside stomata leading to accelerated rate of photosynthesis and decreased the rate of photorespiration in C3 plants (Wingler *et.al.*, 2000). During dry spell PPFM exudates osmo protectants (sugars and alcohols) on the surface of host plants and this matrix helps to protect the plants from desiccation and high temperature (Xoconostle *et.al.*, 2010).

II. REVIEW OF LITERATURE

Effect of drought stress in maize

Maize plants may respond differently to drought stress at different crop stages. Poor establishment and bad plant stand are usually the result of soil drying during or after germination. Among various crop stages, the reproductive stage especially 3-4 weeks bracketing male flowering (anthesis) is the maize crop's most susceptible phase (Grant *et.al*., 1989). Female reproductive structures are more seriously affected than the male flowers (tassels). Extreme sensitivity seems confined to the period 2 to 22 days after anthesis, with a peak at 7 days, and almost complete barrenness can occur if maize plants are stressed in the period from just before tassel emergence to the lag phase of grain-filling (Grant *et.al.*, 1989). When photosynthesis per plant at flowering is reduced by drought, silk growth is delayed, leading to an increase in the anthesis-silking interval (ASI), and kernel and ear abortion (Bolaños and Edmeades, 1996). Leaf senescence begins from the bottom of the plant (older leaves affected first) and proceeds towards the top of the plant. However, in conditions of high evapotranspiration due to combined heat and drought stress, leaf senescence may also occur at the top of the plant (Bolaños and Edmeades, 1996).

Ear and kernel formation during fourteen days bracketing flowering and reduced photosynthesis mechanism and leaf senescence at the time of grain filling (Banziger *et.al.*, 2000). Elongation of stem in maize under drought stress was reduced during vegetative stage. The experiments conducted in green house to study the effect of drought stress on the vegetative growth of maize and it was found that drought stress reduced shoot growth (Ramadan *et.al.*, 1985).

Effect of PPFM on moisture deficit management in crops

PPFM affects the plants positively by production of auxin and cytokinins and influences the root growth to make it grow deeper for avoiding the moisture stress in dry condition. It increases the stomatal count, chlorophyll and malic acid concentration in leaves thereby increasing the net photosynthetic rate (Cervantes-Martínez *et.al.*, 2004). Mirakhori *et.al*. (2009) concluded that methanol spraying had a positive effect on root area to leaf area ratio of soybean. Research on sugar beet showed that methanol foliar application led to increased root length and root volume under drought stress. (Chandrasekaran and Chun, 2016) noticed that application of 2 per cent PPFM recorded an increased root length, root volume, leaf area and specific leaf weight in tomato. Sivakumar *et.al*. (2017) revealed that PPFM (2%) was found superior in improving RWC, photosynthetic rate, SPAD value and proline content. The antioxidant enzyme, catalase activity was enhanced by PPFM (2%). PPFM (2%) treatment gave statistically superior relative water content of 64.42 per cent followed by brassinolide (62.66%) and salicylic acid (61.24%) at 60 DAT in tomato.

III. MATERIALS AND METHODS

The field experiment was conducted at Maize Research Station, Vagarai during late *rabi* (early summer) period of 2018-19 and 2019-20 to evaluate the drought mitigation strategies and irrigation scheduling to increase irrigation use efficiency and grain yield of maize. This experiment was planned in such a manner that to evaluating the different drought mitigation strategies like foliar spraying of drought mitigating materials *viz.*, KCl (1 %) (Potassium Chloride) solution (D_2) and PPFM (1 %) (Pink Pigmented Facultative Methylotrophs) solution (D_3) with control (D_1) at a periodical interval. The drought mitigation materials were sprayed during the critical stages of the crop *viz.*, knee high stage, pre flowering and flowering stage and irrigation was scheduled based on available soil moisture (ASM) at 50 % ASM (S_1), 40 % ASM (S_2), 30 % ASM (S_3) and 20 % ASM (S_4).

The maize hybrid chosen for the experiment was TNAU Maize hybrid Co 6 with the recommended spacing of 60 X 25 cm. The field was prepared with primary and secondary tillage and rectification was done and the ridges were formed with the spacing of 60 cm. The seeds were sown at 5 cm depth from 1/3rd of the height of ridge from base at 25 cm spacing. The plot size designed as 3 x 5 m with 5 rows and 20 plants in a row. The experiment was replicated thrice and used the statistical design for analysis with spit plot design.

The regular cultivation practices *viz.*, pre emergence herbicide atrazine @ 0.25 kg a.i. per hectare was sprayed with flat nozzle hand sprayer on 3 DAS and the life irrigation was given on 4 DAS uniformly to all the treatments for assurance of optimum population. The recommended fertilizer dose of 250: 75: 75 kg NPK per hectare was given as 25 % N + 100 % P_2O_5 and 100 % K_2O at basal, 50 % N at knee high stage and 25 % N at flowering stage was given.

IV. RESULTS AND DISCUSSION

Growth parameters

The plant population of the hybrid maize was significantly shown the effect of drought mitigation strategies as well as irrigation scheduling. A significantly higher plant population (59,220 plants/ha and 59,930 plants/ha) was recorded in control (D_1) and irrigation given at 50 % available soil moisture (S_1) respectively at 25 DAS. Whereas, at harvest stage, the plant population was not significantly differed by the application of drought mitigation methods, which was significantly higher (57,520 plants/ha) in irrigation scheduling at 50 % ASM.

The plant height at 25 DAS was not either influenced by drought mitigation strategies or by irrigation schedules. The plant height was significantly higher (135.2 cm and 142.5 cm respectively) in PPFM (1 %) foliar spray at knee high, pre flowering and flowering stages and irrigation scheduling at 50 % ASM at 50 DAS. The same was significantly higher (195.8 cm) at harvest in irrigation scheduling of irrigation given at 50 % ASM and which was not in drought mitigation strategies followed. This result was evidenced with the findings of Madhaiyan *et.al.*, (2007) that PPFM produces plant growth hormones which is responsible for plant tolerance to biotic and abiotic stresses by inducing system resistance and was found to increase the net photosynthetic rate by regulating the stomatal conductance, increasing chlorophyll content and malic acid concentration in leaves.

Dry matter production is a function of leaf area index and radiation use efficiency. The dry matter production was significantly differed at 25 DAS at drought mitigation strategies as well as at irrigation scheduling. The significant higher dry matter was obtained (6,715 kg/ha and 7,522 kg/ha respectively) in foliar spray of PPFM (1 %) at critical stages and irrigation scheduling at 50 % ASM. There was no significant difference noticed on dry matter production due to imposing of drought mitigation strategies *viz.*, KCl (1 %) and PPFM (1 %) foliar spray compared with control. Whereas, DMP was significantly higher (7,578 kg/ha) at harvest was recorded when the irrigation was given at 50 % ASM. Similar findings were reported that the higher dry matter production recorded in the treatments might be due to increase in plant height and better root development in rice (Aswathy *et.al.* 2020). Further, the growth promoting activity mediated by PPFM might have also aided in the accumulation of photo assimilates in various sinks leading to higher dry matter production. The same was supported by the findings of Thakur *et.al.* (1995), Singh *et.al.* (2004) and Li *et.al.* (2009).

Table 1. Effect of drought mitigation strategies and irrigation scheduling on growth parameters of maize hybrid

Treatments	Plant population ('000/ha)		Plant height (cm)			Dry Matter Production (kg/ha)	
	25 DAS	Harvest	25 DAS	50 DAS	Harvest	25 DAS	Harvest
Drought mitigation method							
D_1 – Control (No mitigation method)	59.22	52.11	44.0	133.3	177.4	6448	6393
D_2 – KCl foliar spray (1%)	58.11	50.33	42.2	129.8	174.5	6715	6065
D_3 – PPFM foliar spray (1%)	57.06	50.44	44.0	135.2	183.2	6557	6130
SEd	0.55	0.93	0.97	0.91	2.75	54.6	198.2
CD (p=0.05)	1.52	NS	NS	2.53	NS	151.5	NS
Irrigation scheduling							
S_1 – Irrigation given at 50 % Available Soil Moisture	59.93	54.52	42.9	142.5	195.8	7522	7578
S_2 – Irrigation given at 40 % Available Soil Moisture	58.74	52.15	44.9	133.9	180.5	6819	6586
S_3 – Irrigation given at 30 % Available Soil Moisture	57.48	48.44	44.2	126.0	175.3	6221	5544
S_4 – Irrigation given at 20 % Available Soil Moisture	56.37	47.74	41.5	128.7	161.9	5730	5075
SEd	1.24	1.59	1.59	2.1	6.6	149.8	204.7
CD (p=0.05)	2.61	3.35	NS	4.4	13.8	214.8	430.0

Yield parameters

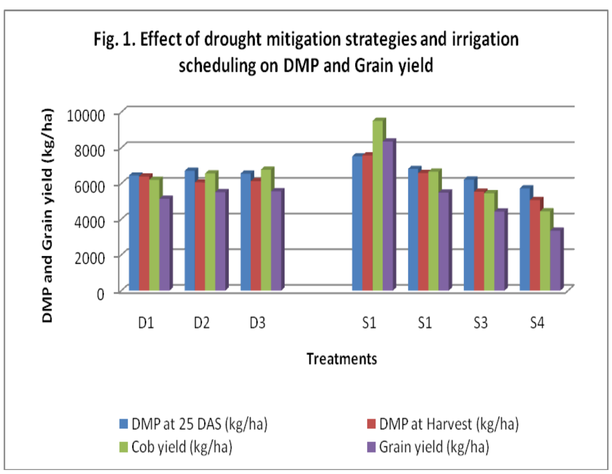
The result of yield parameters revealed that there was no significant difference in number of cobs, cob length, cob girth and 100 grain weight by imposing at critical stages of hybrid maize of drought mitigation strategies. Whereas, the cob yield was significantly higher (6,778 kg/ha) in spraying of PPFM (1 %) foliar spray at critical stages of hybrid maize. As for as irrigation scheduling was concern, the number of cobs per hectare (55,260 cobs/ha) and cob yield (9,508 kg/ha) were significantly higher in irrigation scheduled at 50 % ASM than other scheduling. The parameters *viz.*, cob length, cob girth and 100 grain seed weight of maize were not significantly differed among irrigation scheduling. Potassium application improved yield traits and water productivity under both normal and water stress conditions, but effect was more prominent under water stress conditions than normal conditions. Potassium application also alleviated drought susceptibility of all hybrids (Sami Ul-Allah *et.al.*, 2020).

Table 2. Effect of drought mitigation strategies and irrigation scheduling on yield parameters of maize hybrid

Treatments	No of cobs ('000/ha)	Cob length (cm)	Cob girth (cm)	100 grain weight (g)	Cob yield (kg/ha)
Drought mitigation method					
D1 – Control (No mitigation method)	48.94	15.1	14.7	36.0	6212
D2 – KCl foliar spray (1%)	46.83	15.8	14.6	37.8	6562
D3 – PPFM foliar spray (1%)	48.67	16.0	14.7	38.5	6778
SEd	0.74	0.79	0.53	0.96	140.0
CD (p=0.05)	NS	NS	NS	NS	388.8
Irrigation scheduling					
S_1 – Irrigation given at 50 % Available Soil Moisture	55.26	15.6	14.4	39.8	9508
S_2 – Irrigation given at 40 % Available Soil Moisture	51.11	15.5	14.6	38.1	6663
S_3 – Irrigation given at 30 % Available Soil Moisture	44.59	15.0	14.6	36.4	5458
S_4 – Irrigation given at 20 % Available Soil Moisture	41.63	16.4	14.9	35.5	4440
SEd	1.42	0.81	0.32	0.87	356.1
CD (p=0.05)	2.99	NS	NS	NS	748.1

Yield and economics

Grain yield of maize was significantly higher (5,564 kg/ha) in spraying of PPFM (1 %) at critical stages of maize *viz.*, knee high stage, pre flowering and flowering stages than other drought mitigation methods *viz.*, spraying of KCl (1 %) and control (no mitigation strategy). Whereas, spraying of KCl (1 %) gave the onpar grain yield (5,520 kg/ha) to the PPFM (1 %) spray. As for as irrigation scheduling for maize hybrid was concern, irrigation given at 50 % ASM gave significantly higher grain yield (8,355 kg/ha) than other irrigation schedules. Stover yield was also significantly higher (6,668 kg/ha) in 50 % ASM scheduling interval than other scheduling intervals. The crop water use efficiency was higher (13.31) in irrigation scheduling at 50 % ASM. Radhika *et.al.* (2008) observed that significantly higher maize grain yield (7941 kg/ha) was recorded in PPFM @ 5 litres/ha foliar applied plots. Significantly increased grain yield was due to increase in size and weight of cob and higher number of grains per cob. Similar results were reported in soybean, foliar application of methanol increased the yield up to 38% (Nadali *et.al.*, 2010). Among the foliar application treatments foliar application of PPFM 1% recorded significantly higher grain yield of 6847 kg/ha (Rajasekar *et.al.*, 2019).



The net returns and benefit cost ratio calculated in the study of effect of drought mitigation strategies and irrigation scheduling of maize hybrid was stated that the higher net returns and benefit cost ratio of Rs.40,023/ha and 1.65 respectively in spraying of PPFM (1 %) at critical stages and Rs.88,776/ha and 2.44 respectively in irrigation scheduling of 50 ASM. Rajasekar *et.al.*, (2019). Higher net return (Rs. 63,960) and BC ratio (3.11) was attained under IW/CPE ratio 0.8 and was followed by IW/CPE ratio of 1.0. Among the foliar application treatments foliar application of PPFM @ 1 % recoded higher net return and BC ratio (Rs. 60,923, & 3.02 respectively) and was followed by salicylic acid 0.2 % (Rs. 57,984 & 2.91). In interaction effect irrigating at IW/CPE ratio of 0.8 with foliar application of PPFM 1 % recorded higher net return (Rs. 66,151) and BC ratio (3.17).

Table 3. Effect of drought mitigation strategies and irrigation scheduling on yield and economics of maize hybrid

Treatments	Grain yield (kg/ha)	Stover yield (kg/ha)	CWUE (kg/ha mm)	Net returns (Rs./ha)	BCR
Drought mitigation method					
D1 – Control (No mitigation method)	5145	5028	11.19	37123	1.65
D2 – KCl foliar spray (1%)*	5520	5099	12.04	39333	1.64
D3 – PPFM foliar spray (1%)*	5564	5465	11.89	40023	1.65
SEd	95.5	234.1	--	--	--
CD (p=0.05)	265.1	NS	--	--	--
Irrigation scheduling					
S_1 – Irrigation given at 50 % Available Soil Moisture	8355	6668	13.31	88776	2.44
S_2 – Irrigation given at 40 % Available Soil Moisture	5495	5547	11.51	39923	1.68
S_3 – Irrigation given at 30 % Available Soil Moisture	4431	4602	11.74	22519	1.39
S_4 – Irrigation given at 20 % Available Soil Moisture	3358	3973	10.25	4089	1.08
SEd	343.1	204.5	--	--	--
CD (p=0.05)	720.8	429.5	--	--	--

V. CONCLUSION

From the above study, it was concluded that the drought mitigating strategy of foliar spraying of 1 per cent pink pigmented facultative methylotrophs (PPFM) at critical stages (knee high, pre flowering and flowering stages) of maize hybrid and irrigation given at 50 ASM enhanced the plant growth and yield parameters. Grain yield of maize was significantly higher in spraying of PPFM (1 %) and irrigation given at 50 % ASM. The crop water use efficiency was also higher (13.31) in irrigation scheduling at 50 % ASM. The net returns and benefit cost ratio calculated were shown the higher values in spraying of PPFM (1 %) at critical stages and in irrigation scheduling of 50 % ASM of maize hybrid.

VI. ACKNOWLEDGEMENT

This study was conducted under Tamilnadu Core Funded project. Trials were conducted at Maize Research Ststion, Vagarai, Tamil Nadu Agricultural University. I thank Dr.V.Geethalakshmi, The Director, Directorate of Crop Management, TNAU, Coimbatore, Dr.M.Md.Amanulla, Professor Agronomy and Dr.K.Sethuraman, Professor and Head, MRS, Vagarai for the support of successful conduct of experiment.

REFERENCES

[1] M. Akram. Growth and yield components of wheat under water stress of different growth. 2011.

[2] I.A. Amanullah, H.Z. Irfanullah. Potassium management for improving growth and grain yield of maize (Zea mays

L.) under moisture stress condition. Sci. Rep. 6, 34627. 2016.

[3] M. Aslam, M.S.I. Zamir, I. Afzal, M. Yaseen, M. Mubeen, and A. Shoaib. Drought stress, its effect on maize production and development of drought tolerance through potassium application. Cercet. Agron. Mold. 46, 99–114. 2013.

[4] J.C. Aswathy, P. Shalini Pillai, Jacob John and K.S. Meenakumari. Effect of pink pigmented facultative methylotrophs (PPFM) on growth and growth attributes of rice (*Oryza sativa* L.). International Journal of Chemical Studies 2020; 8(4): 3209-3213. 2020.

[5] M. Banziger. Breeding for drought tolerance in tropical maize conventional approaches and challenges to molecular approaches. In "Molecular approaches for the genetic improvement of cereals for stable production in water-limited environments" (Ribaut, J.-M., ed.), pp. 69-72.CIMMYT, Mexico. 1999.

[6] J. Bolanos and G.O. Edmeades. 8 cycles of selection for drought tolerance in lowland tropical maize. I. Responses in grain yield, biomass, and radiation utilization. Field Crops Research 31:233-252. 1993.

[7] J. Cervantes-martinez, S. Lopez-diaz and B. Rodrigue z-garay. Detection of the effects of *Methylobacterium* in Agave tequilana Weber var. azulby laser induced fluorescence. *Plant Sci.* 166: 889–892. 2004.

[8] Chandrasekaran, Murugesan, Se Chul Chun. Expression of PR-protein genes and induction of defense-related enzymes by Bacillus subtilis CBR05 in tomato (*Solanum lycopersicum*) plants challenged with Erwinia carotovora subsp. carotovora. Bioscience, biotechnology, and biochemistry. 80(11): 2277-2283. 2016.

[9] M. Eldakak, S.I. Milad and A.I.Nawar. Proteomics: a biotechnology tool for crop improvement. Front Plant Sci 4:35. 2013.

[10] J.R. Fiedrick, J.D. Hesketh, D.B. Peters, F.E. Be-low. Yield and reproductive trait responses of maize hybrids to drought stress. Maydica. 34, 319-328. 1989.

[11] R.F. Grant, B.S. Jackson, J.R. Kiniry and G.F. Akrim. Water deficit timing effects on yield components in maize. Agron. J. 81:61-65. 1989.

[12] C. Irvine Irina, A. Brigham Christy, N. Suding Katharine and B.H. Martiny Jennifer. The abundance of pink-pigmented facultative methylotrophs in the root zone of plant species in invaded coastal sage scrub habitat. PloS one. 7(2):31026. 2012.

[13] Z.R. Li, S. Wakao, B.B. Fischer and K.K. Niyogi. Sensing and responding to excess light. Ann. Rev. Plant Biol. 60: 239-260. 2009.

[14] M. Rajasekar, Syed Abul Hassan Hussainy and A. Karthik. Agro-techniques for moisture stress management in maize – A review. The Pharma Innovation Journal. 9(4): 220-231. 2019.

[15] Madhaiyan, Munusamy, Byung-Yong Kim, Selvaraj Poonguzhali, Soon-Wo Kwon, Myung-Hee Song, Jeoung-Hyun Ryu, *et.al.*. Methylobacterium oryzae sp. nov., an aerobic, pink-pigmented, facultatively methylotrophic, 1-aminocyclopropane-1-carboxylate deaminase-producing bacterium isolated from rice. International journal of systematic and evolutionary microbiology. 57(2):326-331. 2007.

[16] I. Nadali, F. Paknejad, F. Moradi, S. Vazan, M. Tookalo, M. Jami Al-Ahmadi. Effects of Methanol on Sugar Beet ('*Beta vulgaris*'). Australian journal of crop science. 4(6):398. 2010.

[17] NCA. National Commission on Agriculture, Government of India, New Delhi. 1976.

[18] S. Radhika, K. Velayutham and N. Thavaprakaash. Effect of nutrients and plant growth regulators on the quality parameters and yield of baby corn (*Zea mays* L.). Int. J. Trop. Agric. 26:255-258. 2008.

[19] H.A. Ramadan, S.N. Al-Niemi and T.T. Hamdan. Water stress, soil type and phosphorus effects on corn and soybean, 1. Effect on growth. Iraqi J. Agri. Sci, "Sanco" 3:1237-144. 1985.

[20] Sami Ul-Allah, Muhammad Ijaz, Ahmad Nawaz, Abdul Sattar, Ahmad Sher, Muhammad Naeem, Umbreen Shahzad, Umar Farooq, Farukh Nawaz and Khalid Mahmood. Potassium Application Improves Grain Yield and Alleviates Drought Susceptibility in Diverse Maize Hybrids. Plants 9, 75. 2020.

[21] U. Singh, Y. Singh and V. Kumar. Effect of weed management and cultivars on boro rice and weeds. Indian J Weed Sci. 36(1-2):57-59. 2004.

[22] R. Sivakumar, G.K. Nandhitha, P. Chandrasekaran, P. Boominathan and M. Senthilkumar. Impact of Pink Pigmented Facultative Methylotroph and PGRs on Water Status, Photosynthesis, Proline and NR Activity in Tomato under Drought. Int.J.Curr.Microbiol.App.Sci (2017) *6*(6): 1640-1651. 2017.

[23] R. Thakur, R. Singh and R. Chaudhry. Prabhat- a very early maturing rice variety released in Bihar. Int. Rice Res. Newsletter. 20(2):11-12. 1995.

[24] Wingler Astrid, Peter J Lea, Paul Quick W and Richard C Leegood. Photorespiration: metabolic pathways and their role in stress protection. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences. 355(1402):1517-1529. 2000.

[25] C.B. Xoconostle, Francisco Arturo Ramirez Ortega, Leonardo Flores Elenes and Roberto Ruiz Medrano. Drought tolerance in crop plants. American Journal of Plant Physiology. 5(5):241-256. 2010.