Journal of Cereal Research

14 (1): 97-102

Homepage: http://epubs.icar.org.in/ejournal/index.php/JWR

Research Article

Enhancing crop productivity, water and nitrogen use efficiency of *kharif* maize through planting methods, mungbean intercropping and nitrogen management practices

Mo Danish, Mukesh Kumar*, B. Pramanick, S. K. Singh and Mohammad Hashim#

*Department of Agronomy, Dr. Rajendra Prasad Central Agriculture University, Pusa, Samastipur- 848125 (Bihar)
Scientist, ICAR- IARI, Regional Station Pusa, Samastipur- 848125 (Bihar)

Article history:
Received: 07, Mar., 2022
Revised: 19, Apr., 2022
Accepted: 04, May, 2022

Citation:
Danish M, Kumar M, Pramanick B, Singh SK and Hashim M. 2022. Enhancing crop productivity, water and nitrogen use efficiency of *kharif* maize through planting methods, mungbean intercropping and nitrogen management practices. *Journal of Cereal Research* ***14 (1):*** *97-102.* *http://doi.org/10.25174/2582-2675/2022/123995*

****Corresponding author:***
E-mail: mukesh.agro@gmail.com

Abstract

A field experiment was carried out during *kharif* season of 2020 at research farm of Dr Rajendra Prasad Central Agricultural University (RPCAU), Pusa, Samastipur, Bihar to find out the effect of planting methods, mung intercropping and nitrogen management on system productivity, water and nitrogen use efficiency of *kharif* maize. The experiment was laid out in split plot design with four planting methods *viz.,* M_1-Flat sown maize, M_2- Bed planting maize, M_3- Flat sown maize + mungbean, M_4- Bed planting maize + mungbean in main plot and four nitrogen management practices *viz.,* N_1- 120:50:40:: $N:P_2O_5:K_2O$ kg ha^{-1}, N_2- 100:50:40:: $N:P_2O_5:K_2O$ kg ha^{-1}, N_3-80:50:40:: $N:P_2O_5:K_2O$ kg ha^{-1}, N_4- 0:50:40:: $N:P_2O_5:K_2O$ kg ha^{-1} (control plot) in sub-plot replicated thrice. Bed planting maize + mungbean recorded the highest maize grain yield (3.17 t ha^{-1}), stover yield (4.5 t ha^{-1}), system productivity (5.05 t ha^{-1}), water use efficiency (WUE) (11.74 kg ha^{-1}mm), water productivity (133.10 ₹ m^{-3}) and nitrogen use efficiency (NUE) (5.86 kg kg^{-1}). Among N management options, application of 120 N kg ha^{-1} recorded the maximum grain yield of maize (3.67 t ha^{-1}), stover yield (4.43 t ha^{-1}), system productivity (4.68 t ha^{-1}), WUE (10.82 kg ha^{-1} mm), water productivity (117.70 ₹ m^{-3}) and NUE (7.98 kg kg^{-1}).

Key words: Bed planting, Maize, Mung bean, System productivity, NUE and WUE

1. Introduction

Maize is a multi-dimensional crop, consumed as food, feed, fodder and grown throughout world. Maize has a significant role in food safety as well as dietary protection through quality protein (Rawool, 2004). It is widely recognized for being a heavy feeder of nutrients, need to rationalize the nutrients use of this crop. Besides, it is also very sensitive of water stress which leads to yield reduction and there is need to relook its sowing methods to avoid water stress. One of the reasons for lower productivity of *kharif* maize due to its cultivation under rainfed where drought, heavy rain, water logging conditions occurred frequently. Water and nitrogen are precious input for agriculture need to use judiciously and precisely (Yadav *et al.* 2016). Conventional flat sowing and flood irrigation is commonly used for growing maize and both of these methods not have efficient utilization of irrigation and nitrogen (Humphreys *et al.,* 2010). Though, the bed planting has many advantages, use of legumes in intercropping is reliable and practical option to efficient use of water and nitrogen. It optimizes resource use efficiency and boost production per unit area (Zhang *et al.,* 2007). Intercropping of cereals with leguminous crop is known to ensure better utilization of nutrient, improves soil fertility and increase in nitrogen use efficiency which leads to production enhancement. Green gram or mungbean or golden gram, is one among the most crucial short duration pulse crop cultivated in our country. It is quite versatile crop grown for seed, green manure and forage, contains highly nutritive value protein (23 -24%), carbohydrates, minerals and vitamins (Chadha 2010). Hence, it is hypothesized that changing the planting methods of maize and mung bean intercropping and nitrogen doses may enhance and/or stabilize the productivity of *kharif* maize. Therefore, an experiment has planned to different planting methods and N management for getting higher productivity of *kharif* maize.

2. Materials and methods

A field experiment was carried out during *kharif* season of 2020 at research farm of Dr Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar under the middle Gangetic zone of Agro climatic India. This zone located at the southern and western bank of the river Budhi Gandak at 25°59' N and 85°48' E with an altitude of 52.92 msl. The soil was saline with a pH of 8.5. The experimental soil had low level of soil organic carbon (0.46%), N (229 kg ha^{-1}), K (91.57 kg ha^{-1}) and a moderate in available P (12.25 kg ha^{-1}). The climatic condition of region was sub-tropical categorized predominantly by hot dry summer with cool winter. Rainfall received approximately 974 mm during experimental period July to October (*Kharif* season). The average T_{max} during the July to November varied between 34.08 °C to 29.65 °C and the average T_{min} was about 15.70 °C and the T_{max} was about 26.47 °C (fig 1). The experiment was laid out in split plot design with four planting methods in main plot *viz.,* M_1- Flat sown maize, M_2- Bed planting maize, M_3- Flat sown maize + mungbean, M_4- Bed planting maize + mungbean and four nitrogen management practices in sub-plot *viz.,* N_1- 120:50:40:: N:P_2O_5:K_2O kg ha^{-1}, N_2-100:50:40:: N:P_2O_5:K_2O kg ha^{-1}, N_3-80:50:40:: N:P_2O_5:K_2O kg ha^{-1}, N_4- 0:50:40:: N:P_2O_5:K_2O kg ha^{-1} (control plot) with three replication. Maize (*var.* shaktiman-5) and mungbean (var. IPM 205-7 or Virat), was sown with seed rate of 20 kg ha^{-1} and 12.5 kg ha^{-1}, respectively, on 16th July. The full dose of phosphorous and potash was applied as basal, while nitrogenous fertilizer as per treatment applied in three splits i.e. 1/3rd applied as basal , 1/3rd at 35 DAS (knee high stage) and remaining 1/3rd was applied at 80 DAS (flowering stage). At harvest stage, observations on yield attributes and yield of maize were recorded. The data recorded for different parameters were statistically analyzed with the help of analysis of variance (ANOVA) technique as suggested by Gomez and Gomez (1984) for a Split Plot design (SPD). The results are presented at 5% level of significance (P= 0.05) for making comparison between treatments.

2.1. Maize equivalent yield (MEY) and system productivity (t ha^{-1})

The MEY of mungbean was calculated and based on minimum support price (MSP) using the following calculation formula and represented in t ha^{-1}

$$\text{MEY} = \text{Mungbean yield} \times \frac{Market\ value\ of\ mungbean\ (₹\ t^{-1})}{Market\ value\ of\ maize\ (₹\ t^{-1})}$$

System productivity = Maize yield obtained (t ha^{-1}) + MEY (t ha^{-1}) of mungbean.

2.2. Water use efficiency (WUE)

The WUE is the yield of crop obtained per unit of water applied either by irrigation or by effective rainfall. Here, there was not a single irrigation applied due to rainfall, hence WUE was calculated based on effective rainfall (ER) (Molden *et al.,* 2010).

$$\text{Water use efficiency} = \frac{\text{Yield (t ha}^{-1})}{\text{ER (ha mm)}}$$

Effective rainfall (ER) was calculated by USDA SCS methods through CROPWAT software.

2.3. Water productivity

The water productivity was calculated in term of net income per unit of water used using following formula (Molden *et al.,* 2010).

$$\text{Water productivity} = \frac{\text{Net income (₹ ha}^{-1})}{\text{ER (m}^3)}$$

Agronomic N- use efficiency: It indicate the increase in yield per kilogram of N (%) applied (Dobermann, 2007)

$$\text{Agronomic N- use efficiency-} \frac{Y_a - Y_0}{N_a}$$

Y_a – Crop yield obtained with nutrient application

Y_0- Crop yield obtained with-out nutrient application

N_a = Amount of nutrient applied to the crop (kg ha^{-1})

$$\text{Nitrogen Harvest Index (NHI)} = \frac{\text{N uptake in grain ((kg ha}-1)}{\text{Total N uptake by plant ((kg ha}-1)}$$

$$\text{Partial factor productivity (PFP)} = \frac{\text{Crop yield obtained (kg ha}-1)}{\text{Amount of N fertilizer applied (kg ha}-1)}$$

3. Results and discussion

3.1. Grain yield and system productivity of maize

The results of our study revealed an increased in about 66% and 11% of system productivity in bed planting maize + mungbean compared flatbed sowing sole maize and flat sown maize + mung bean intercropping, respectively (table 1).. It was a significant increase of system productivity (5.05 t h^{-1}) in bed planting maize + mungbean compared to sole maize sown either on flat or bed. However, the grain yield of maize was found non significant among all planting methods. Highest system productivity in bed planting maize + mungbean would be due to excellent growth conditions, especially for root which minimized lodging, and ensured effective water and nitrogen usage during *kharif*/rainy season led to higher yield. Our results are also in conformity with the findings of Khan and Shafi (2008). Among all the nitrogen management options, 120 kg N ha^{-1} treated plot recorded the highest maize grain yield (3.67 t ha^{-1}) and system productivity (4.68 t ha^{-1}). System productivity was significantly higher over rest of the treatments but grain yield was found non -significant. While, the minimum value was found with plot received no nitrogen application. This finding also noted by Gul *et al.* (2015) and they stated that with the application of different nitrogen levels it has a linear impact on maize grain yield. Nitrogen plays an important role on crop production and it has positive impact on biomass production up to optimum dose i.e. N at 120 kg ha^{-1}. Nitrogen was applied in three split doses i.e. 1/3rd as basal, 1/3rd at 35 DAS and 1/3rd at 80 DAS only to provide proper dose during peak demand stage and to reduced losses due heavy rain in *kharif* season. It was evident from weather data that during experimental year there was too high rainfall compared to long term data of (60-80 mm) in July month. Maximum rainfall (205 mm) received during 29th meteorological weeks (16-22 July) and precipitation in July and August was 438 and 154.8 mm, respectively, and was coincided with sowing of crop to vegetative growth stage of maize and N application as well (fig. 1). This created water logged situation during initial crop growth which was drained out from experimental plot, but the drained may wash out the N applied to crops (Sogbedji et al 2000). But due to split application the response had significant in yield attributes and yield of maize.

3.2. Nitrogen use efficiency (NUE), Partial factor productivity (PFP) and Nitrogen harvest index (NHI)

Bed planting maize + mungbean had the maximum NUE, PFP and NHI, however, none of these parameters were significantly increased over flat sown of maize(Table 1). This might be due lack of considerable increased in maize yield as it should have been to increased NUE and NHI. But when 120 kg N ha^{-1}applied it significantly increased the NUE and NHI over lower doses of N particularly 80 and 0 kg N ha^{-1}. Significantly, highest NUE (9.16 kg kg^{-1}) and NHI (0.80) were recorded with the application of 120 kg N ha^{-1}. It might be due to the effect of split and proper dose of N to the crop. As intermittent rainfall at the time of basal and various crop growth stages and drained out excess water led to loss of N. the higher dose i.e. 120 might be bale to provide some amount of N despite loss but lower doses could not able to provide N as much as higher. These results were corroborated with Sogbedji, *et al.*, (2000) and Sitthaphanit, *et al.,* (2010). They conformed and supported that in crop heavy precipitation (rainfall) NUE can be lowered, especially on that time of nutrient application because it leads to occurs soil erosion and high nutrient losses too from the field. Scharf *et al.*, (2006) reported that crop yield was almost equal when provided with higher (115 kg ha^{-1}) and lower nitrogen doses (69 kg ha^{-1}). It could be possible due to inadequate nitrogen absorption by crop, as significant N losses from leaching and runoff in heavy rainfall comparison to appropriate and evenly distributed rainfall.

3.4. Water use efficiency and water productivity

Significantly, higher water use efficiency (11.74 kg ha^{-1} mm) and water productivity (133.11 ₹ m^{-3}) was obtained in bed planting maize + mungbean than rest of the planting methods. This might be attributable to an increase in yield as well as more efficient water usage (Table 1). Our results are also corroborated with Wang *et al.,* (2004). Comparison to traditional flat sowing methods, the raised bed sowing needed 30% lesser irrigation led to enhanced WUE by 20% (Ahmad *et al.* 2011). The lowest WUE and water productivity were recorded in flat sown maize and these results were corroborated with Khan *et al.,* (2012). They stated that compared to flat-planted maize, ridge-planted maize had the maximum grain yield and WUE.

Among nitrogen management option, 120 kg N ha^{-1}applied treatment obtained the highest WUE (10.82 kg

Journal of Cereal Research 14(1): 97-102

Table 1: Effect of planting methods and nitrogen management on grain yield, system productivity, NUE, PFP and NHI, WUE and WP of *Kharif* maize

Treatment	Grain yield ($t\ ha^{-1}$)	System productivity ($t\ ha^{-1}$)	NUE ($kg\ kg^{-1}$)	PFP ($kg\ kg^{-1}$)	NHI	WUE ($kg\ ha^{-1}\ mm$)	WP (₹ m^{-3})
Planting methods							
M_1: Flat sown maize	3.05	3.08	3.85	24.10	0.76	7.15	65.09
M_2: Bed planting maize	3.08	3.17	5.28	24.34	0.77	7.36	69.58
M_3: Flat sown maize + mungbean	3.08	4.82	5.44	24.41	0.78	11.20	123.11
M_4: Bed planting maize + mungbean	3.17	5.05	5.59	25.33	0.79	11.74	133.10
SEm±	0.11	0.16	0.40	1.08	0.003	0.37	6.67
LSD ($p \leq 0.05$)	NS	0.55	NS	NS	NS	1.27	23.06
Nitrogen management ($N:P_2O_5: K_2O$ kg ha^{-1})							
N_1- 120:50:40	3.67	4.68	9.16	30.56	0.80	10.82	117.70
N_2 - 100: 50:40	3.20	4.10	6.42	32.00	0.78	9.54	102.49
N_3- 80: 50:40	2.85	3.77	4.58	35.63	0.76	8.77	92.53
N_4- 0: 50:40	2.65	3.58	0.00	0.00	0.75	8.32	78.15
SEm±	0.08	0.07	0.38	0.66	0.005	0.17	9.85
LSD ($p \leq 0.05$)	0.23	0.21	1.11	1.92	0.014	0.50	NS
Interaction							
SEm±	0.16	0.15	0.76	1.31	0.01	0.34	19.70
LSD ($p \leq 0.05$)	NS	0.45	NS	NS	NS	NS	NS

NUE- Nitrogen use efficiency, PFP- Partial factor productivity, NHI- Nitrogen harvest index, WUE- Water use efficiency, WP- Water productivity ha^{-1} mm and water productivity (117.70 ₹ m^{-3}). The lowest WUE (8.32 kg ha^{-1} mm) and water productivity (78.15 ₹ m^{-3}) was obtained in plot received no nitrogen. Nitrogen plays an important role in enhancing crop growth and their biomass and thereby yield attributes and yield. Hence, the WUE and water productivity was recorded higher in higher dose of N.

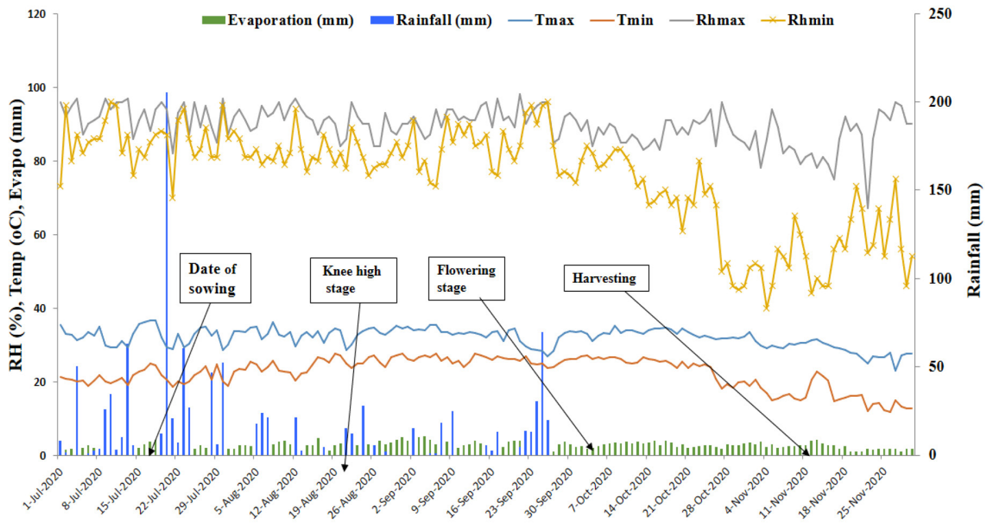

Fig 1. Weather parameters during experiment

3.5. Economics profitability

The bed planting maize+ mungbean system fetched the highest net return (54996.00 ₹ ha^{-1}) and benefit-cost (B: C) ratio (1.26) whilst, the lowest value of those in flat sown maize (Table 2). It was obvious that cost involved for preparing bed was higher than flat sowing but because the system productivity was higher led to higher income from bed planting. Similarly, among N management practices, 120 kg N ha^{-1} fetched the highest net return (52935 ₹ ha^{-1}) and benefit-cost (B: C) ratio (1.24) while, the lowest of all these parameters with N controlled. The higher quantity of N led to higher cost of production, nevertheless, higher income from 120 kg N ha$^{-1,}$ only due to higher system productivity results of effective N utilization.

Table 2: Impact of planting methods and nitrogen management on economics of Kharif maize

Treatment	Net Return (₹ ha^{-1})	B: C ratio
Planting methods		
M_1: Flat sown maize	26198	0.68
M_2: Bed planting maize	29608	0.78
M_3: Flat sown maize + mungbean	52963	1.11
M_4:Bed planting maize+ mungbean	54996	1.26
SEm±	3084	0.07
LSD (p≤0.05)	10673	0.26
Nitrogen management (**N: P_2O_5: K_2O kg ha^{-1}**)		
N_1- 120:50:40	52935	1.24
N_2 - 100:50:40	42580	1.00
N_3- 80:50:40	35585	0.84
N_4- 0:50:40	32666	0.76
SEm±	1528	0.03
LSD (p≤0.05)	4460	0.10
Interaction		
SEm±	3056	0.07
LSD(p≤0.05)	NS	NS

4. Conclusion

From the study, it may be concluded that the intercropping of maize with mungbean had a considerable impact on maize growth, yield and yielding attributes. The intercropping of maize + mungbean under bed planting system with prescribed amount of 120:50:40::N:P_2O_5:K_2O kg ha^{-1} significantly augmented the system productivity, water use efficiency, nitrogen usage efficiency, net return, and B: C ratio than rest of the treatment.

5. References

1. Ahmad RN, M Arshad and MA Shahid. 2011. Raised bed technology for crop water productivityof maize and cotton. ICID 21st *International Congress on Irrigation and Drainage*.15-23.
2. Chadha, ML. 2010. Short duration mungbean: a new success in South Asia. Asia-Pacific Association of Agricultural Research Institutions. FAO RAP, Bangkok, Thailand. Pp. 55.
3. Dobermann, A. 2007. Nutrient use efficiency – measurement and management. In "IFA International Workshop on Fertilizer Best Management Practices", Brussels, Belgium, p1-28
4. Gul S, MH Khan, BA Khanday and S Nabi. 2015. Effect of sowing methods and NPK levels on growth and yield of rainfed maize. https://doi.org/10.1155/2015/198575
5. Humphreys E, SS Kukal, EW Christen, GS Hira, B. Singh, and S. Sharma, 2010. Halting the groundwater decline in North-West India – which crop technologies will be winners. *Advances in Agronomy*. **109**: 155–217.
6. Khan, MB, F Yousaf, M Hussain, MW Haq, DJ Lee and M Farooq. 2012. Influence of planting methods on root development, crop productivity and water use efficiency in maize hybrids. *Chilean Journal of Agricultural Research*.**72:** 556–563.
7. Khan, MI and M. Shafi. 2008. Response of maize varieties to different nitrogen levels. M.Sc. Thesis, Department Agronomy, Peshawar Agriculture university, Pakistan
8. Molden, D., Oweis, T., Steduto, P., Bidraban, P., Hanjra, M.A., Kijne, J. 2010. Improving agricultural water productivity: Between optimism and caution. *Agricultural Water Management* 97: 528-535.
9. Rawool, HV. 2004. Effect of integrated nutrient management on yield and nutrient balance in maize (*Zea mays L.*). *Indian Journal* of *Agricultural* Sciences. **46** (4): 698-701.
10. Scharf P, J Lory and J. Grundler. 2006. A manual on best management practices for nitrogen fertilizer in Missouri. MU Extension, University of Missouri-Columbia. http://ipm.missouri.edu.
11. Sitthaphanit S, V. Limpinuntana, B. Toomsan, S Panchaban and RW Bell. 2010 Growth and yield responses in maize to split and delayed fertilizer applications on sandy soils under high rainfall regimes. *Kasetsart Journal (Natural Science)*. **44:** 991-1003.
12. Sogbedji JM, HM Van , CL Yang, LD Geohring and FR Magdoff 2000. Nitrate leaching and nitrogen budget as affected by maize nitrogen rate and soil type, *Journal of Environmental Quality*.**29:** (6) 61813–1820
13. Swaminathan MS. 1998. Crop production and sustainable food security in crop productivity and sustainability shaping the future. Chopra, V. L., Singh, R. B. and Verma, A. Proceeding of the 2nd International *Crop Science Congress,* New Delhi, India. Pp. 3-18.
14. Wang F., W Xuqing, and KD Sayre. 2004. Comparison of conventional, flood irrigated, flat planting with furrow irrigated, raised bed planting for winter wheat in China. *Field Crops Research.* **87:** 35-42
15. Yadav MR, CM Parihar, RK Verma , RK Yadav, RH Yadav, M Singh and A Sharma. 2016. Performance of maize under conservation tillage. *International Journal of Agriculture Sciences*.**8:** 0975-9107
16. Zhang LW, S Werf , Zhang, B Li and JHJ. Spiertz. 2007. Growth, yield and quality of wheat and cotton in relay strip intercropping systems. *Field Crops Research*. **103:** 178- 188.