Journal of Root Crops
Indian Society for Root Crops
ISSN 0378-2409, ISSN 2454-9053 (online)
Journal homepage: https://journal.isrc.in

Spacio-temporal fertigation effects on yield, nutrient use efficiency and economics of greater yam+maize intercropping system

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Abstract

A field experiment was conducted for three seasons (2017-2018, 2018-2019 and 2019-2020) at the Regional Centre of Indian Council of Agricultural Research ICAR-Central Tuber Crops Research Institute (CTCRI) at Bhubaneswar, Odisha, India to find out the spacio-temporal fertigation effects on yield, nutrient use efficiency and economic of greater yam (*Dioscorea alata* L.) + maize (*Zea mays* L.) intercropping system. The experiment was laid out in split plot design with fertigation interval in main plots (I_1-2 days, I_2-3 days and I_3-4 days) and in sub plots number of splits (S_1-40 splits, S_2-50 splits and S_3-60 splits). Control (soil application at basal (40%), 45 (30%) and 90 (30%) days after planting) also included to compare the treatments. The treatments were replicated thrice. The results revealed that treatment I_1 resulted in significantly higher maize seed yield compared to other treatments. However, maximum greater yam tuber and tuber equivalent yield was noticed in treatment I_2. The treatment S_3 resulted in lower maize seed yield and higher greater yam tuber, and tuber equivalent yield. The interaction effect was found significant. The treatment I_1S_1 resulted in greater maize seed yield (3.2 t ha^{-1}) compared to other treatments. However, the treatment I_2S_3 resulted in higher greater yam tuber yield (37.0 t ha^{-1}) and tuber equivalent yield (39.4 t ha^{-1}). The treatment I_3S_1 was statistically on par with I_2S_3 regarding greater yam tuber (35.9 t ha^{-1}) and tuber equivalent yield (37.9 t ha^{-1}). The drip fertigation treatments I_2S_3 resulted in higher nutrient use efficiency of 106.5 kg of greater yam tuber equivalent yield per kg of nutrient (NPK) application. The treatment I_2S_3 resulted in higher gross (₹5,91,000 ha^{-1}) and net (₹3,80,000 ha^{-1}) returns compared to other treatments. Thus, fertigation of N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1} in 60 splits at 3 days interval was recommended for greater yam + maize intercropping system for higher system yield, nutrient use efficiency, gross and net returns.

Keywords : Fertigation interval, Greater yam, Maize, Nutrient use efficiency, Split application, Tuber equivalent yield

Introduction

Greater yam (*Dioscorea alata* L.) + maize (*Zea mays* L.) is a popular intercropping system in eastern India (Nedunchezhiyan et al., 2022). Greater yam is a trailing herb, and it requires staking. Wooden or bamboo staking is a costly input in greater yam cultivation. Hence, maize is grown as intercrop in greater yam mainly for providing staking support to greater yam. Hence, in this system, maize cobs are harvested at physiological maturity stage from the plants leaving stems/haulms in the field which continue supporting greater yam. In this intercropping, maize gives grain yield apart from staking support to

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Received: 23 October 2023; Revised: 10 November 2023; Accepted: 12 November 2023

greater yam. It is a complementary interaction type of intercropping system. Greater yam, being a long duration (9-10 months) crop, cultivated commercially under protective irrigation. The commonly used method of irrigation is surface flood irrigation which requires huge quantity of water because of high evaporation and seepage loss. Further, it is difficult for application of surface flood irrigation 3 months after planting due to huge canopy developed in greater yam + maize intercropping system. Under such conditions, drip irrigation is right option. Drip irrigation supplies water directly to the root zone of the crop through a network of pipes with the help of emitters. Since it supplies water directly to the crop instead of land, as followed in the flood irrigation, the water losses occurring through evaporation and distribution are completely absent (Dhawan, 2002). The on-farm irrigation efficiency of properly designed and managed drip irrigation system is estimated to be about 90% (Nedunchezhiyan et al., 2020). Nedunchezhiyan et al., (2021a) recommended drip irrigation at 100% of cumulative pan evaporation (CPE) during 1-90 days after planting (DAP) + 80% of CPE during 91-270 DAP was optimum for greater yam + maize intercropping system.

Nutrient management for greater yam + maize intercropping is necessary to achieve high yields. For the greater yam + maize intercropping system, a fertilizer dose of N-P_2O_5-K_2O 100-75-100 kg ha^{-1} along with mulching (2 t ha^{-1} dried farm waste) is recommended for economic yield (Nedunchezhiyan et al., 2010). Application of N-P_2O_5-K_2O 120-90-120 kg ha^{-1} to the greater yam + maize intercropping system resulted in improved greater yam tubers and maize yield (Sahoo *et al*., 2006). The top dressing of fertilizers in greater yam + maize intercropping is very difficult due to spreading canopy development after the third month. Hence, drip fertigation is an option for nutrient management for the greater yam + maize intercropping system. Nedunchezhiyan et al., (2021b) reported that drip fertigation of N-P_2O_5-K_2O 140-90-140 kg ha^{-1} was found optimum for higher yield and nutrient use efficiency. Long duration crops respond very well to split application of fertilizer/fertigation. More number of splits, more the nutrient use efficiency. Fertigation of recommended fertilizers in 40-50 splits resulted in higher yield and nutrient use efficiency in elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) (Nedunchezhiyan et al., 2017). Frequency of fertigation also plays a significant role in growth and development of crop species and nutrient use efficiency. The fertigation at 3-4 days interval resulted in maximum corm yield, nutrient (N, P and K) uptake and use efficiency (agronomic efficiency, recovery efficiency and partial factor productivity) in elephant foot yam (Nedunchezhiyan et al., 2018). Very few studies were conducted on drip fertigation for greater yam + maize intercropping system in India and elsewhere in the world, but very meager information is available on scheduling of fertigation. Keeping in view of the above, an investigation was conducted to study the spacio-temporal fertigation effects on yield, nutrient use efficiency and economic of greater yam + maize intercropping system.

Materials and Methods

A field experiment was conducted for three seasons (2017-2018, 2018-2019 and 2019-2020) at the Regional Centre of Indian Council of Agricultural Research ICAR-Central Tuber Crops Research Institute (CTCRI). (20°14′53.25″ N, 85°47′25.85″ E, 33m above mean sea level) at Bhubaneswar, Odisha, India. The soil was an alfisol with 13.9% water content at permanent wilting point, 28.2% water content at field capacity, 1.53 g cc^{-1} bulk density, 6.8 pH, 0.41% organic carbon, 201 kg ha^{-1} available N, 21.5 kg ha^{-1} available P, and 285 kg ha^{-1}available K in the top 0.30 m. The experiment was laid out in split plot design with fertigation interval in main plots (I_1-2 days, I_2-3 days, and I_3-4 days) and in sub plots number of splits (S_1-40 splits, S_2-50 splits and S_3-60 splits). Control (soil application of nutrients) was also included to compare the treatments. A fertilizer dose of N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1} was applied in all the treatments. The treatments were replicated thrice. Farmyard manure 10 t ha^{-1} was incorporated in the last plough in all the treatments. In fertigation treatments, water soluble N, P and K fertilizers (urea, urea phosphate and potassium sulphate) were used and applied as per treatments. In the case of control treatment, urea, single super phosphate and muriate of potash were used. In control treatment full P_2O_5 was applied in the last plough. N and K were applied in 3 splits at basal (40%), 45 days after planting (DAP) (30%) and 90 DAP (30%). The drip irrigation level of 100% of cumulative pan evaporation (CPE) during 1-90 DAP at 80% of CPE during 91-270 DAP was followed with emitter spacing of 30cm and flow rate of 4 L h^{-1}.

The greater yam variety Sree Nidhi weighing 200 g cut tubers were planted on ridge tops formed at 90cm spacing at 5-7cm depth. The plant-to-plant distance of 90cm was maintained. In intra-rows, between 2 greater yam plants, 3 hybrid maize seeds (*var*. MRM 3777) were sown at 2-3cm depth at 30cm spacing on the same day. Plant populations of 12345 and 37037 plants ha^{-1} for greater yam and maize, respectively, were established.

During the first, second and third season, greater yam and maize were planted/sown on 17 April 2017, 19 April 2018 and 15 April 2019, respectively. Weeding followed by earthing up was done at 30 and 60 DAP. Maize cobs were harvested at physiological maturity (90 DAP) and stalks and leaves left in the field to serve as stakes for the greater yam. Maize cobs were harvested during the first, second and third season on 16 July 2017, 20 July 2018 and14 July 2019 respectively. Irrigation was withheld for 10 days before harvesting of greater yam in all the treatments. Greater yam was harvested at 280 DAP. During the first, second and third season, greater yam was harvested on 22 January 2017, 24 January 2018 and 20 January 2020, respectively.

The tuber equivalent yield (TEY) data was computed taking into consideration the selling price of maize and greater yam along with their yield.

$$\text{TEY (t ha}^{-1}\text{)} = \frac{\text{Maize yied (t ha}^{-1}\text{)} \times \text{Sale price of maize (₹ t}^{-1}\text{)}}{\text{Sale price of greater yam (₹ t}^{-1}\text{)}} \quad \text{...Eqn (1)}$$

The nutrient use efficiency (NUE) was calculated by using the following formula (Eqn. 2).

$$\text{NUE} = \frac{\text{TEY (kg ha}^{-1}\text{)}}{\text{NPK (kg ha}^{-1}\text{) applied}} \quad \text{... Eqn. (2)}$$

The data collected were subjected to analysis of variance (ANOVA) in split plot as well as randomized block design using statistical software SAS (SAS 2010). Treatment means were compared for significance at the 0.05 level of probability using the least significant differences (CD) as suggested by (Gomez and Gomez, 1984).

Results and Discussion

The results revealed that spacio-temporal fertigation application had significant effects on maize and greater yam yields (Table 1). The treatment I_1 (2 days interval) resulted in significantly higher maize seed yield compared to other treatments. It indicates that maize requires fertilizers in quick succession for its robust growth and development. The greater yam tuber yield and tuber equivalent yield (TEY) were increased with increasing fertigation interval. However, maximum greater yam tuber and tuber equivalent yield was noticed in treatment I_2 (3 days interval). Greater yam being a long duration and widely spaced crop could be unable to utilize nutrients, if supplied in quick succession. However, delayed application also affected the tuber yield. Nedunchezhiyan et al., (2017) also reported that for elephant foot yam fertigation at 3 days interval was ideal. Increasing number of splits of the recommended dose of fertilizer decreased maize seed yield, whereas increased greater yam tuber and tuber equivalent yield (Table 1). The treatment S_3 resulted in lower maize seed yield and higher greater yam tuber, and tuber equivalent yield (Table 1). The former case may be due to insufficient quantity of fertilizer received by the maize crop during crop growth period (90 days) and the latter case may be due to availability of fertilizer for longer period for the longer duration greater yam crop. An eight-month duration elephant foot yam crop was responded to up to 50 splits of drip fertigation application (Nedunchezhiyan et al., 2018).

Table 1. Effects of fertigation interval and number of splits on maize, greater yam and tuber equivalent yields (pooled)

Treatment	Maize yield (t ha^{-1})	Greater yam yield (t ha^{-1})	TEY (t ha^{-1})
Fertigation interval			
I_1	3.0	31.7	34.7
I_2	2.5	34.7	37.3
I_3	1.7	33.9	35.6
SEm±	0.02	0.28	0.29
CD @5%	0.1	1.1	1.1
Number of splits			
S_1	2.6	32.9	35.5
S_2	2.4	33.1	35.5
S_3	2.2	34.3	36.5
SEm±	0.02	0.26	0.26
CD @5%	0.1	0.8	0.8

The interaction effect of fertilizer interval and number of splits was found significant (Table 2). The treatment I_1S_1 (40 splits in 2 days interval) resulted in greater maize seed yield (3.2 t ha^{-1}) compared to other treatments. The maize seed yield reduction was drastic with increased fertigation interval and number of splits. Significantly lowest maize seed yield was observed in I_3S_3 (60 splits in 4 days interval). It indicated that maize utilized maximum of the applied N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1}, if applied in lesser interval and number of splits. This is because maize is a short duration crop (90 days). However, fertigation of N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1}in 60 splits at 3 days interval (I_2S_3) resulted in higher greater yam tuber yield (37.0 t ha^{-1}) and tuber equivalent yield (39.4 t ha^{-1}) (Table 2). The treatment I_3S_1 was statistically on par with I_2S_3 with regard to greater yam tuber and tuber equivalent yield. It indicated that if fertigation interval is increased, the dosage of fertilizer in each split should be increased. However, fertigation period should be of minimum 160 days and maximum

180 days for greater yam. The relationship between fertigation duration and greater yam tuber equivalent yield in Fig. 1 indicated that when fertigation duration was increased, the greater yam tuber equivalent yield was increased sharply up to 160 days. Between 160 days and 180 days a plateau was found. After 180 days, greater yam tuber equivalent yield was slowly decreased (Fig. 1). Thus, fertigation beyond 180 days after planting was not helpful for greater yam tuber bulking. This might be due to decreased nutrients absorption by roots towards maturity of the greater yam crop. Nedunchezhiyan et al., (2017) reported that in an eight-month duration elephant foot yam drip fertigation response was found up to 150-160 days after planting. The treatment I_2S_3 resulted in 29.4 and 26.7% higher greater yam yield tuber and tuber equivalent yield respectively over control (NPK soil application). Similarly, the treatment I_3S_1 resulted in 25.5 and 21.9% higher greater yam tuber yield and tuber equivalent yield respectively over control. This clearly showed that drip fertigation with more number of splits resulted in 25.5-29.4% higher greater yam tuber yield and 21.9-26.7% higher greater yam tuber equivalent yield than soil application with three splits (control) (Table 2).

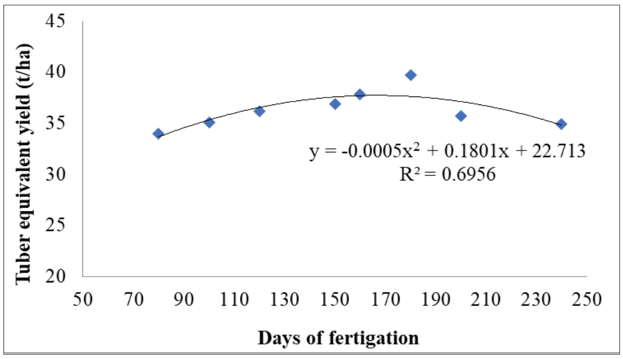

Fig. 1. Relationship of fertigation duration and yam tuber equivalent yield

Table 2. Interaction effects of fertigation interval and number of splits on maize, greater yam and tuber equivalent yields (pooled)

Treatment	Maize yield (t ha^{-1})	Greater yam yield (t ha^{-1})	TEY (t ha^{-1})	Nutrient use efficiency (kg kg^{-1})
I_1S_1	3.2	30.0	33.2	89.7
I_1S_2	2.9	31.6	34.5	93.2
I_1S_3	2.8	33.4	36.2	97.8
I_2S_1	2.6	32.7	35.3	95.4
I_2S_2	2.5	34.5	37.0	100.0
I_2S_3	2.4	37.0	39.4	106.5
I_3S_1	2.0	35.9	37.9	102.4
I_3S_2	1.7	33.2	34.9	94.3
I_3S_3	1.5	32.5	34.0	91.9
C (NPK)	2.5	28.6	31.1	84.1
SEm±	0.06	0.52	0.52	1.45
CD @5%	0.1	1.5	1.5	4.2

The nutrient use efficiency (NUE) computed for drip fertigation and control treatments revealed that all the drip fertigation treatments resulted in higher nutrient use efficiency than control (soil application of NPK with three splits) (Table 2). The drip fertigation treatment I_2S_3 resulted in higher nutrient use efficiency of 106.5 kg of greater yam tuber equivalent yield per kg of nutrient (NPK) application. It is followed by the treatment I_3S_1 (102.4 kg kg^{-1}). The treatments I_2S_3 and I_3S_1 resulted in 22.4 and 18.3% higher nutrient use efficiency than control. The drip fertigation treatment having minimum days of drip fertigation interval (2 days) and minimum number of splits (40 splits) (I_1S_1) also resulted in higher nutrient use efficiency of 6.7% over control. The lowest nutrient use efficiency was noticed in control treatment. This indicated that the drip fertigation was better than control (NPK soil application).

Spacio-temporal fertigation has significantly influenced cost of cultivation, gross return, net return and B: C ratio (Table 3). The treatments I_2S_3 and I_3S_1 resulted in higher cost of cultivation compared to other treatments. This was due to higher harvest cost owing to higher yield of greater yam tubers. Significantly lowest cost of cultivation was observed with control. This was due to lower harvesting cost because of lower maize seed and greater yam tuber yields as well as lower irrigation cost. The treatment I_2S_3 (60 splits at 3 days interval) resulted in higher gross and net returns compared to other treatments (Table 3). Nedunchezhiyan et al., (2023) also reported more number of splits resulting in higher yield. However, it was statistically on par with the treatment I_3S_1. This was due to higher greater yam tuber yield in these treatments. The lowest gross and net returns were noticed in the control treatment (Table 3). This was due to lower maize seed and greater yam tuber yields. The treatment I_2S_3 resulted in a higher B: C ratio compared to other treatments. However, it was statistically on par with the treatment I_3S_1. This was due to higher gross return in these treatments. Significantly the lowest B: C ratio was observed in the treatment I_1S_1. This was due to lower gross return and higher cost of cultivation.

Thus, it can be concluded that fertigation of $N-P_2O_5-K_2O$ @ 140-90-140 kg ha^{-1}in 60 splits at 3 days interval was recommended for greater yam + maize intercropping system for higher system yield, nutrient use efficiency, gross and net returns.

Table 3. Economics of fertigation in greater yam + maize intercropping system

Treatment	Cost of Cultivation (₹ ha^{-1})	Gross Return (₹ ha^{-1})	Net Return (₹ ha^{-1})	B: C ratio
I_1S_1	205300	498300	293000	2.34
I_1S_2	206600	518200	311500	2.51
I_1S_3	208300	542800	334500	2.61
I_2S_1	207400	529500	322100	2.55
I_2S_2	209100	559000	349900	2.67
I_2S_3	211500	591500	380000	2.80
I_3S_1	210000	568500	358500	2.71
I_3S_2	207000	523200	316200	2.53
I_3S_3	206100	513800	307800	2.49
C (NPK)	179800	465800	286100	2.59
SEm±	500	7900	7400	0.03
CD @5%	1500	23200	21700	0.10

References

Dhawan, B.D. 2002. *Technological Change in Indian Irrigated Agriculture: A Study of Water Saving Methods*. Commonwealth Publishers, New Delhi, India.

Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research*. John Wiley & Sons, New York.

Nedunchezhiyan, M., Byju, G. and Jata, S.K. 2021a. Drip fertigation for greater yam (*Dioscorea alata*) and maize (*Zea mays*) intercropping. *Indian Journal of Agricultural Sciences* **91**(9): 1302-1306. https://doi.org/10.56093/ijas.v91i9.116074.

Nedunchezhiyan, M., Byju, G., Naskar, S.K. and Mukherjee, A. 2010. Effect of mulching and graded doses of fertilizer on yield and nutrient uptake of greater yam + maize intercropping system. *Indian Journal of Horticulture* **67** (special issue): 283-287.

Nedunchezhiyan, M., Byju, G., Ravi, V. and James George. 2017. Spacio-temporal fertigation effects on growth, yield and nutrient use efficiency of elephant foot yam (*Amorphophallus paeoniifolius*). *American-Eurasian Journal of Agriculture & Environmental Science* **17**(1): 63-77.

Nedunchezhiyan, M., Byju, G., Ravi, V. and James George. 2018. Effect of fertigation schedule on production potential, quality and nutrient uptake of elephant-foot yam (*Amorphophallus paeoniifolius*). *Curr. Hortic.*, **6** (1): 19-26.

Nedunchezhiyan, M., Kalidas Pati, Chauhan, V.B.S. and Arutselvan, R. 2023. Analysis of benefit: cost ratio in drip irrigation and fertigation in greater yam *(Dioscorea alata)* + maize *(Zea mays)* intercropping system. *Curr. Hortic.*, **11** (1): 57-60. https://doi.org/10.5958/2455-7560.2023.00013.4

Nedunchezhiyan, M., Kalidas Pati, Chauhan, V.B.S. and Jata, S.K. 2021b. Enhancing factor productivity of a greater yam+maize intercropping system under drip fertigation. *J. Root Crops,* **47** (1&2): 9-15.

Nedunchezhiyan, M., Pati, K., Chauhan, V.B.S., Arutselvan, R., Laxminarayana, K., Byju, G. and Veena, S.S. 2020. Growth, dry matter production and yield characteristics of greater yam+maize intercropping system under varied drip irrigation and fertigation levels. *J. Root Crops,* **46** (2): 14-22.

Nedunchezhiyan, M., Suja, G. and Ravi, V. 2022. Tropical root and tuber crops-based cropping systems-a review. *Curr. Hortic.* **10**(1):14-22. http://doi.org/10.5958/2455-7560.2022.00003.6.

Sahoo, T.R., Dora, D.K., Rout, K.K. and Nedunchezhiyan, M. 2006. Productivity and economic return of a yam (*Dioscorea alata*)-Maize intercropping system in an acid soil as influenced by fertilizer level and mulching. *Current Agriculture Research,* **19**(1-4): 20-25.