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Growth, Dry Matter Production and Yield Characteristics of Greater Yam+Maize Intercropping System Under Varied Drip Irrigation and Fertigation Levels

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Abstract

Field experiments were conducted during 2015-16 and 2016-17 to study the influence of drip irrigation and fertigation on growth, dry matter production and yield characteristics of greater yam+maize intercropping system. The treatments comprised of a combination of three levels of drip irrigation [I_1- at 80% of cumulative pan evaporation (CPE) during 1-270 days after planting (DAP), I_2-at 100% of CPE during 1-90 DAP + at 80% of CPE during 91-270 DAP and I_3-at 100% of CPE during 1-270 DAP] in main plots and four levels of fertigation (F_1-N-P_2O_5-K_2O @ 100-90-100 kg ha^{-1}, F_2-N-P_2O_5-K_2O @ 120-90-120 kg ha^{-1}, F_3-N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1} and F_4-N-P_2O_5-K_2O @ 160-90-160 kg ha^{-1}) in sub plots along with a control (surface irrigation treatment at 100% of CPE; soil application of N-P_2O_5-K_2O @ 120-90-120 kg ha^{-1}). Drip irrigation at I_3 resulted in higher maize and greater yam growth and dry matter production. The treatment F_4 resulted in greater yam and maize growth and dry matter production. The interaction effects revealed that highest maize yield was recorded in I_3F_4 whereas the treatment I_2F_4 resulted in higher greater yam yield. However, maize and greater yam yield in the treatment I_2F_3 was found statistically at par with I_3F_4 in maize and I_2F_4 in greater yam. The treatments control (surface irrigation at 100% of CPE with soil application of N-P_2O_5-K_2O @ 120-90-120 kg ha^{-1}) and I_1F_2 [drip irrigation at I_1 with fertigation of same level of nutrients (F_2)] resulted in same level of maize and greater yam yields. Thus, drip irrigation saved 0.684-0.710 million litre (17.9-25.9%) of water per ha. Same level of maize and greater yam yields with the treatments control and I_2F_1/I_3F_1 also indicated a saving of nutrients N-K_2O @ 20-20 kg ha^{-1} (20%) under drip fertigation. Considering water and fertilizer use efficiency and response, the treatment I_2F_3 (irrigation at 100% of CPE during 1-90 DAP + at 80% of CPE during 91-270 DAP with N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1}) is recommended for greater yam+maize intercropping system.

Key words: Maize, greater yam, intercropping, dry matter production, tuber

Introduction

Greater yam (*Dioscorea alata* L.) is a starchy tuber crop grown widely in African, Asian and Latin American countries (Mignouna et al., 2003; Saski et al., 2015). In India, it is a subsistence food crop in tribal and hilly areas and in other parts it is a vegetable cash crop (Nedunchezhiyan and Sahoo, 2019). Generally greater yam is trailed on wooden stakes and perennial trees. Nedunchezhiyan et al. (2006) reported maize as an intercrop, which serves as live staking for greater yam. Greater yam+maize intercropping system is becoming popular in traditional greater yam growing areas. Due to the effect of climate change, irrigation is gaining importance for greater yam+maize intercropping system for achieving higher productivity and profitability.

Water is the scarcest commodity and its use efficiency is increased in agriculture by drip irrigation system (Playan and Mateos, 2006). Drip irrigation supplies water directly to the root zone of the crop instead of land, as followed in the flood method of irrigation. The available research results revealed that the productivity gain due to drip method of irrigation was estimated to be in the range of 20 to 90% for different crops (INCID, 1994; Nedunchezhiyan et al., 2017; Jata et al., 2018 and 2019). Further, surface irrigation becomes cumbersome at later stages [6 months after planting (MAP)] due to lodging of maize and greater yam crops. Under such situations, drip irrigation could be a better option for greater yam+maize intercropping system. Few studies conducted on greater yam alone or along with intercrops under drip irrigation indicated higher yield and system productivity. Nutrient management for greater yam+maize intercropping is vital to achieve higher yields. For greater yam+maize intercropping system, soil application of N-P_2O_5-K_2O @ 100-75-100 kg ha^{-1} along with mulching (2 t ha^{-1} dried farm waste) was found optimum for economic yield under Bhubaneswar, Odisha conditions (Nedunchezhiyan et al., 2010). However, Sahoo et al. (2006) reported that greater yam+maize intercropping system responded to application of N-P_2O_5-K_2O @ 120-90-120 kg ha^{-1}. Fertigation is a method of nutrient application through irrigation water which improves nutrient use efficiency by applying directly into the root zone (Patel and Rajput, 2000; Chawla and Narda, 2002). The information on growth, dry matter production and yield characteristics of greater yam+maize intercropping system under drip irrigation and fertigation is not available. Hence, the present investigation was carried out to study the effects of drip irrigation and fertigation levels on growth, dry matter production and yield characteristics of greater yam+maize intercropping system.

Materials and Methods

Field experiments were conducted for two seasons (2015-16 and 2016-17) at the Regional Centre of ICAR-Central Tuber Crops Research Institute, Bhubaneswar, Odisha. The climate of the location is a hot and humid summer, and a cool and dry winter. The experimental site soil was alfisols having pH 6.8, organic carbon 0.39%, available N 196 kg ha^{-1}, available P 21.4 kg ha^{-1} and available K 265 kg ha^{-1}. The experiment was laid out in split plot design with three replications. Main plots treatments comprised of three drip irrigation levels [I_1- at 80% of cumulative pan evaporation (CPE) during 1-270 days after planting (DAP), I_2-at 100% of CPE during 1-90 DAP + at 80% of CPE during 91-270 DAP and I_3-at 100% of CPE during 1-270 DAP] and four fertigation levels(F_1-N-P_2O_5-K_2O @ 100-90-100 kg ha^{-1}, F_2-N-P_2O_5-K_2O @ 120-90-120 kg ha^{-1}, F_3-N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1} and F_4-N-P_2O_5-K_2O @ 160-90-160 kg ha^{-1}) in sub plots. A control (surface irrigation treatment at 100% of CPE; soil application of N-P_2O_5-K_2O @ 120-90-120 kg ha^{-1}) treatment was also included to compare with the drip irrigation and fertigation treatments. Water soluble N, P and K fertilizers (urea, urea phosphate and potassium sulphate) were applied in five equal splits (basal, 30, 60, 90 and 120 DAP) through drip irrigation in fertigation treatments. In control treatment, the full P_2O_5 (single super phosphate) was applied to soil as a basal application. N (urea) and K (muriate of potash) were applied to soil in three split applications, basal (40%), 45 DAP (30%) and 90 DAP (30%). Drip irrigation on alternate days was given as per treatment through 4 lph drippers placed 30 cm spacings on the laterals based on CPE considering pan factor 0.7.

Row to row spacing of 90 cm was adopted by forming ridges. The greater yam accession ‘Da 293’ cut tubers weighing approximately 200 g were planted at 90 cm spacing on the ridges. On the same day hybrid maize ‘MRM 3777’ seeds were sown at 30 cm spacing in between two greater yam plants in the intra-rows. Greater yam 12345 plants and maize 37037 plants per ha^{-1} were accommodated in this system. During first and second season, greater yam and maize were planted/sown on 17th April 2015 and 22nd April 2016, respectively. Maize cobs were harvested 3 MAP and left the haulms in the field. Irrigation was withheld 20 days before harvesting of greater yam and it was harvested 290 DAP. Maize and greater yam were harvested on 15th July 2015 and 31st January 2016 during first season, 20th July 2016 and 5th February 2017 during second season, respectively.

Maize growth and dry matter production observations were recorded at 3 MAP, whereas greater yam growth parameters were recorded at 3, 4, 5 and 6 MAP, whereas dry matter production per plant was recorded at 3, 4, 5 and 6 MAP as well as at harvest. The partitioning of greater yam dry matter into shoot and tuber was accounted.

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). The homogeneity of error variance was tested using Bartlett's test. As the error variance was homogeneous, pooled analysis of two years data was done. Comparison of treatment means for significance at 5% level of probability was done using the critical differences (CD) as suggested by Gomez and Gomez (1984).

Results and Discussions

Irrigation

The rainfall received during first (2015-16) and second (2016-17) cropping season was 980.0 and 1238.5 mm, respectively. The amount of water applied through drip irrigation was 383, 432 and 451 mm under I_1, I_2 and I_3 treatments, respectively during first cropping season. During second season, the amount of water applied through drip irrigation was 274, 301 and 345 mm under I_1, I_2 and I_3 treatments, respectively. In control treatment irrigation water applied was 451 mm during first cropping season and 345 mm during second cropping season.

Performance of maize

Drip irrigation and fertigation levels significantly influenced maize plant height and dry matter production per plant (Table 1). The treatment I_3 resulted in significantly higher plant height and dry matter production per plant. However, it was on par with I_2. It is well known that maize takes up and utilize large amounts of soil moisture due to its high dry matter production. The increase in plant height and dry matter production of I_3 over I_2 was negligible, because in both the treatments equal quantity of water was applied during 1-90 DAP (until the harvest of maize cobs at physiological maturity). Increasing fertigation levels increased the maize plant height and dry matter production per plant (Table 1). The treatment F_4 resulted in higher dry matter production per plant. However, it was statistically comparable with F_3. Maize is a heavy feeder of nutrients. Mukherjee (2008) and Nedunchezhiyan et al. (2008) reported similar findings. Adequate supply of NPK might have increased chlorophyll formation, cell elongation and division, enzymes involved in various metabolic processes, nucleotide, protein etc. that led to more production and translocation of photosynthates towards growth and development of maize (Patel and Rajput, 2000; Chawla and Narda, 2002; Manickasundaram et al., 2002).The drip fertigation treatment I_3F_4 resulted in higher maize plant height. However, it was on par with I_3F_3, I_2F_4, I_2F_3, I_3F_2, I_2F_2 and I_1F_4. Maximum dry matter production of maize was noticed in I_3F_4 and it was followed by I_3F_3, I_2F_4, I_2F_3, I_3F_2 and I_2F_2. The plant height in control treatment was significantly lower than the treatments I_3F_4, I_3F_3, I_3F_2, I_2F_4, I_2F_3, I_2F_2 and I_1F_4, whereas dry matter production of maize in control treatment was significantly lower than the treatments I_3F_4, I_3F_3, I_3F_2, I_2F_4, I_2F_3, I_2F_2, I_1F_4 and I_1F_3. Drip irrigation and fertigation provided water and nutrients directly to the root zone of plants with apparent greater efficiency than surface irrigation with soil application of nutrients. The plant height of maize in control treatment was statistically comparable with the treatments I_1F_2, I_1F_3, I_3F_1, I_2F_1 and I_1F_1 whereas dry matter production of maize in control treatment was on par with I_1F_2, I_3F_1, I_2F_1 and I_1F_1.

Drip irrigation and fertigation levels significantly influenced maize yield attributes (Table 1). The treatment I_3 resulted in significantly higher number of grains per cob, 100 grain weight and grain yield per plant. However, it was statistically on par with I_2. Increasing fertigation levels had increased number of grains per cob, 100 grain weight and grain yield per plant (Table 1). The treatment F_4 resulted in higher number of grains per cob, 100 grain weight and grain yield per plant. However, it was statistically comparable with F_3. The combination of higher levels of irrigation with higher levels of fertigation (I_3F_4, I_3F_3, I_2F_4 and I_2F_3) resulted in higher number of grains per cob, 100 grain weight and grain yield per plant than combination of lower levels of drip irrigation and fertigation. The number of grains per cob, 100 grain weight and grain yield per plant in control treatment was statistically on par with I_3F_1, I_2F_1 and $I_1F_1$and significantly lower than all other treatments. Drip irrigation and fertigation levels significantly influenced maize yield per hectare (Table 1). The treatment I_3 resulted in significantly higher maize yield, but it was statistically at par with I_2. This was due to higher yield attributes. Increasing fertigation levels increased the maize yield. The treatment F_4 resulted in significantly higher maize yield than the other treatments. This was due to higher yield attributes. Drip fertigation levels revealed that maximum maize yield was recorded in I_3F_4. However, it was statistically at par with maize yield of plants under the treatments I_3F_3, I_2F_4 and I_2F_3. The control treatment resulted in on par maize yield with I_3F_2 and I_2F_2 and lower yield than I_3F_4, I_3F_3, I_2F_4 and I_2F_3. Under surface flood irrigation, weeds can be major competitors for water and nutrients. In water

Table 1. Plant height, dry matter production, yield attributes and yield of maize as influenced by drip fertigation levels in greater yam+maize intercropping system (Pooled average)

Treatment	Plant height (cm) at 3 MAP	Dry matter production plant^{-1} (g) at 3 MAP	No. of grains cob^{-1}	100 grain weight (g)	Grain yield plant^{-1} (g)	Maize yield (t ha^{-1})
Irrigation						
I_1	185	262	308	23.0	71	2.5
I_2	193	282	333	23.6	79	2.9
I_3	197	288	336	23.8	80	2.9
CD (P=0.05)	5	9	11	0.6	6	0.2
Fertigation						
F_1	180	247	293	22.7	66	2.4
F_2	191	278	325	23.4	76	2.7
F_3	196	290	341	23.7	81	2.9
F_4	200	295	345	24.0	83	3.0
CD (P=0.05)	7	6	9	0.5	4	0.1
Interaction						
I_1F_1	176	228	272	22.4	61	2.2
I_1F_2	180	258	303	22.8	69	2.6
I_1F_3	188	276	325	23.1	75	2.6
I_1F_4	194	284	332	23.5	78	2.8
I_2F_1	178	250	300	22.7	68	2.5
I_2F_2	195	286	335	23.6	79	2.8
I_2F_3	198	294	347	23.9	83	3.0
I_2F_4	200	298	350	24.0	84	3.1
I_3F_1	184	262	306	22.9	70	2.5
I_3F_2	197	290	336	23.8	80	2.8
I_3F_3	201	300	351	24.2	85	3.0
I_3F_4	205	302	352	24.4	86	3.1
Control	179	252	298	22.8	69	2.6
CD (P=0.05)	11	10	17	0.9	8	0.2

and nutrient stressed fields, weeds can absorb water and nutrients more efficiently than the crop (Singh et al., 2014; Nedunchezhiyan, 2017).

Performance of greater yam

Greater yam vine length increased with advancing crop age (Table 2). Increasing irrigation levels increased the vine growth. The treatment I_3 resulted in significantly higher vine length at 3, 4, 5 and 6 MAP. Under no water stressed conditions, greater yam continued the cell elongation and cell division that led to vine growth. The next best treatment was I_2. The incremental increase in fertigation levels increased the vine growth (Table 2). The treatment F_4 resulted in significantly higher vine length at 3, 4, 5 and 6 MAP. The next best treatment was F_3. The drip fertigation treatments significantly influenced the vine growth of greater yam (Table 2). Longest plants were noticed in the treatment I_3F_4 at all stages of growth and it was followed by I_3F_3. The vine length in control treatment was significantly lower than the treatments I_3F_4, I_3F_3, I_3F_2, I_3F_1, I_2F_4 and I_2F_3 at 3, 4, 5 and 6 MAP. However, vine length in control treatment was statistically comparable to the treatments, I_1F_4 and I_1F_3 at 3 and 4 MAP, I_2F_1 at 5 MAP, and I_2F_2, I_2F_1 and I_1F_4 at 6 MAP. The vine length in control treatment was superior to the treatments I_1F_1, I_1F_2, I_1F_3 and I_1F_4 at all stages of crop growth. The number of leaves per plant increased upto 5 MAP and then declined (Table 2). The treatment I_3 resulted in significantly more

Table 2. Growth characters of greater yam as influenced by drip fertigation levels in greater yam+maize intercropping system (Pooled average)

Treatment	Vine length (cm) at				Number of leaves at			
	3 MAP	4 MAP	5 MAP	6 MAP	3 MAP	4 MAP	5 MAP	6 MAP
Irrigation								
I_1	121	264	326	368	57	125	178	88
I_2	180	349	391	420	72	157	193	99
I_3	204	378	419	446	87	165	209	119
CD (P=0.05)	11	13	10	24	3	7	12	7
Fertigation								
F_1	150	300	353	387	61	128	182	91
F_2	167	327	373	403	70	144	190	98
F_3	173	338	390	423	75	155	197	105
F_4	183	355	398	432	82	170	204	113
CD (P=0.05)	3	5	4	6	5	4	5	5
Interaction								
I_1F_1	105	230	295	340	48	105	170	82
I_1F_2	120	265	325	360	53	115	180	86
I_1F_3	125	270	340	380	62	138	178	90
I_1F_4	135	290	345	390	65	143	185	95
I_2F_1	160	320	370	400	63	138	176	90
I_2F_2	175	340	385	410	68	150	185	95
I_2F_3	185	355	400	430	72	155	200	100
I_2F_4	200	380	410	440	84	185	210	110
I_3F_1	185	350	395	420	73	140	200	102
I_3F_2	205	375	410	440	88	167	205	114
I_3F_3	210	390	430	460	90	172	212	125
I_3F_4	215	395	440	465	96	182	218	134
Control	140	290	365	400	78	158	212	118
CD (P=0.05)	9	9	8	18	4	7	8	7

number of leaves per plant at 3, 4, 5 and 6 MAP. The next best treatment was I_2. The incremental increase in fertigation levels increased the number leaves per plant (Table 2). The treatment F_4 resulted in significantly more number of leaves per plant at 3, 4, 5 and 6 MAP. The next best treatment was F_3. The drip fertigation treatments significantly influenced the number of leaves per plant of greater yam (Table 2). Maximum number of leaves per plant was observed in the treatment I_3F_4 at all stages of growth which was followed by I_3F_3. The number of leaves per plant in control treatment was significantly lower than the treatments I_3F_4, I_3F_3, I_3F_2 and I_2F_4 at 3 and 4 MAP, and I_3F_4 at 5 and 6 MAP, respectively. However, number of leaves per plant in control treatment was statistically comparable to the treatments I_1F_4 and I_1F_3 at 3 and 4 MAP, I_2F_1 at 5 MAP and I_2F_2, I_2F_1 and I_1F_4 at 6 MAP, respectively. The number of leaves per plant in control treatment was superior to the treatments I_1F_1, I_1F_2, I_1F_3, I_1F_4, I_2F_1 and I_2F_2 at all stages of crop growth.

Greater yam dry matter production and partitioning in to shoot and tuber was recorded at 3, 4, 5, 6 MAP and harvest (Table 3). The treatment I_3 resulted in higher shoot dry matter production at all stages of crop growth which was followed by I_2. This was due to higher growth attributes (vine length and number of leaves per plant) (Table 2). Among fertigation treatments, F_4 registered highest shoot dry matter production at all the stages of

Table 3. Greater yam dry matter production (g $plant^{-1}$) and partitioning as influenced by drip fertigation levels in greater yam+maize intercropping system (Pooled average)

Treatment	3 MAP			4 MAP			5 MAP			6 MAP			Harvest		
	Shoot	Tuber	Total	Shoot	Tuber	Total	Shoot	Tuber	Total	Shoot	Tuber	Total	Shoot	Tuber	Total
Irrigation															
I_1	123	8	132	223	38	261	286	76	362	371	131	502	320	521	841
I_2	143	12	154	247	44	290	311	87	398	404	167	571	342	585	927
I_3	147	11	158	252	44	297	320	85	405	411	158	570	349	559	908
CD (P=0.05)	4	2	3	6	7	8	14	5	32	11	5	35	5	34	25
Fertigation															
F_1	121	6	127	219	28	247	282	61	343	328	108	436	306	468	774
F_2	131	9	140	240	43	283	302	76	377	398	130	529	338	553	891
F_3	145	12	158	249	48	297	314	95	408	423	176	599	348	597	945
F_4	153	13	166	255	49	304	326	99	425	433	194	627	357	601	958
CD (P=0.05)	3	2	4	6	2	5	7	4	7	4	2	13	4	6	17
Interaction															
I_1F_1	110	6	116	195	20	215	260	54	314	320	96	416	290	424	714
I_1F_2	120	7	127	225	40	265	285	76	361	365	117	482	320	520	840
I_1F_3	128	9	137	232	45	277	295	85	380	398	142	540	332	568	900
I_1F_4	135	11	146	240	47	287	302	90	392	402	168	570	340	570	910
I_2F_1	125	6	131	230	27	257	290	57	347	330	114	444	310	510	820
I_2F_2	135	13	148	245	48	293	300	73	373	412	138	550	345	588	933
I_2F_3	150	14	164	252	49	301	320	96	416	430	199	629	352	620	972
I_2F_4	160	14	174	260	50	310	335	100	435	445	216	661	360	622	982
I_3F_1	128	7	135	232	36	268	295	72	367	335	113	448	318	470	788
I_3F_2	138	8	146	250	40	290	320	78	398	418	136	554	348	552	900
I_3F_3	158	14	172	262	50	312	326	103	429	440	188	628	360	602	962
I_3F_4	155	14	179	265	51	316	340	107	447	452	197	649	372	612	984
Control	120	12	132	220	49	269	275	92	367	360	171	531	312	486	798
CD (P=0.05)	6	4	7	11	5	9	14	7	23	9	4	30	7	33	36

crop growth (Table 3). More photosynthate production and accumulation is favoured by adequate supply of NPK nutrients (Nedunchezhiyan et al., 2017). The combination of higher level of irrigation with higher level of fertigation (I_3F_4, I_3F_3, I_2F_4 and I_2F_3) resulted in higher shoot dry matter production than the other combinations of drip irrigation and fertigation. The shoot dry matter production in control treatment was significantly lower than the treatments, I_3F_4, I_3F_3, I_3F_2, I_2F_4, I_2F_3, I_2F_2, I_1F_4 and I_1F_3 at all stages of crop growth (Table 3). The treatment I_2 resulted in higher tuber dry matter production at all stages of crop growth which was followed by I_3 (Table 3). At optimum level of irrigation the dry matter was partitioned more effectively in to sink (tuber), whereas at higher level of irrigation the dry matter was partitioned more towards source (shoot). Among fertigation treatments, F_4 resulted in highest tuber dry matter production at all the stages of crop growth (Table 3). The treatments I_3F_4, I_3F_3, I_2F_4 and I_2F_3 resulted in higher tuber dry matter production than the other treatments at all stages of crop growth. The tuber dry matter production in control treatment did not find any trend at early stages, but at harvest it was significantly lower than the treatments, I_2F_4, I_2F_3, I_3F_4, I_3F_3, I_2F_2, I_3F_2, I_1F_4 and I_1F_3 (Table 3). The total dry matter production was higher with I_3 at 3, 4 and 5 MAP. But at 6 MAP and harvest it was higher with I_2. This was due to higher dry matter accumulation in shoot in former case and tuber in latter case (Table 3). Among fertigation treatments, F_4 produced highest total dry matter production at all the stages of crop growth (Table 3). Greater source and sink size in this treatment was favoured by adequate supply of NPK. The combination of higher level of irrigation with higher level of fertigation (I_3F_4, I_3F_3, I_2F_4 and I_2F_3) resulted in higher total dry matter production than the combination of lower levels of drip irrigation and fertigation. The total dry matter production in control treatment was significantly lower than all levels of drip irrigation and fertigation combinations, except the treatments I_1F_1, I_2F_1, I_3F_1 and I_1F_2 (Table 3).

Drip irrigation and fertigation levels significantly influenced greater yam yield attributes (Table 4). The treatment I_2 resulted in significantly greater tuber length, tuber girth and tuber yield per plant. At optimum irrigation level, the dry matter was efficiently partitioned into shoot and tuber. However, it was statistically on par with I_3. Increasing fertigation levels increased tuber length, tuber girth and tuber yield per plant (Table 4). The treatment F_4 resulted in higher tuber length, tuber girth and tuber yield per plant. However, it was statistically on par with F_3. The combination of higher levels of irrigation with higher levels of fertigation (I_3F_4, I_3F_3, I_2F_4 and I_2F_3) resulted in higher tuber length, tuber girth and tuber yield per plant than the combination of lower levels of drip irrigation and fertigation. The tuber length and tuber girth in control treatment was statistically on par with I_3F_1, I_3F_2, I_2F_1, I_1F_3, I_1F_2 and I_1F_1 and significantly lower than all other treatments. The tuber yield per plant in control treatment was statistically comparable to I_3F_1, I_2F_1, I_1F_2 and I_1F_1 and significantly lower than all the other treatments. Drip irrigation and fertigation levels significantly influenced greater yam yield (Table 4). The treatment I_2 resulted in significantly higher greater yam yield, but it was statistically at par with I_3 (Table 4). Increasing fertigation levels increased the greater yam yield (Table 4). The treatment F_4 resulted in significantly higher greater yam yield than the other treatments. Nedunchezhiyan et al. (2008) and Remya and Byju (2020) reported maximum greater yam yield at greater levels of nutrient application. The drip fertigation treatment I_2F_4 resulted in significantly higher greater yam yield (Table 4). However, it was statistically at par with the treatments, I_2F_3 and I_3F_4 (Table 4). Decreased yield response to successive increase of irrigation and nutrient levels have been reported in many crops (Behera et al., 2013). Thus, the physical optimum requirement of irrigation and nutrient levels in this experiment was reached at I_2F_3.

The greater yam tuber yield in I_2F_1 was comparable to the control treatment. In control treatment, the quantity of water applied through surface irrigation was equal to I_3 and nutrients applied in soil was equal to F_2. Thus there is a saving of 0.684-0.710 million litre (17.9-25.9%) of water per ha under drip irrigation. Same level of greater yam tuber yield with the treatments control and I_2F_1/I_3F_1 also indicated a saving of nutrients N-K_2O @ 20-20 kg ha^{-1} (20%) under drip fertigation over soil application. In control treatment, the production and translocation of photosynthates to greater yam tuber was less owing to non-availability of sufficient water and nutrients at later stages due to loss of water and nutrients apart from heavy weed infestation, which removed considerable amount of water and nutrients from the soil.

Table 4. Yield and yield attributes of greater yam as influenced by drip fertigation levels in greater yam+maize intercropping system (Pooled average)

Treatment	Tuber length (cm)	Tuber girth (cm)	Tuber yield/ plant (g)	Tuber yield (t ha^{-1})
Irrigation				
I_1	41	36	2590	30.0
I_2	45	40	2911	34.4
I_3	43	38	2780	32.0
CD (P=0.05)	2	3	146	1.6
Fertigation				
F_1	38	34	2340	27.2
F_2	43	38	2737	31.5
F_3	45	40	2958	34.5
F_4	46	41	3007	35.2
CD (P=0.05)	2	2	113	1.5
Interaction				
I_1F_1	36	32	2120	24.8
I_1F_2	41	36	2570	29.9
I_1F_3	42	38	2820	32.4
I_1F_4	44	39	2850	32.9
I_2F_1	39	35	2550	29.6
I_2F_2	45	40	2910	33.5
I_2F_3	47	42	3075	37.0
I_2F_4	48	42	3110	37.4
I_3F_1	38	34	2350	27.3
I_3F_2	42	37	2730	31.3
I_3F_3	46	40	2980	34.1
I_3F_4	46	41	3060	35.3
Control	39	35	2420	28.3
CD (P=0.05)	3	4	162	2.4

Conclusion

The drip fertigation level I_3F_4 (irrigation at 100% of CPE during 1-270 DAP with N-P_2O_5-K_2O @ 160-90-160 kg ha^{-1}) resulted in greatest maize yield due to higher growth, dry matter production and yield attributes, whereas the treatment I_2F_4 (irrigation at 100% of CPE during 1-90 DAP + at 80% of CPE during 91-270 DAP with N-P_2O_5-K_2O @ 160-90-160 kg ha^{-1}) resulted in higher greater yam yield due to higher tuber dry matter production and yield attributes. However, maize and greater yam yield in the treatment I_2F_3 (irrigation at 100% of CPE during 1-90 DAP + at 80% of CPE during 91-270 DAP with N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1}) was found optimum due to higher dry matter partitioning efficiency. This treatment also resulted in higher maize and greater yam yield compared to control (surface irrigation treatment at 100% of CPE; soil application of N-P_2O_5-K_2O @ 120-90-120 kg ha^{-1}) treatment. The treatments control (surface irrigation at 100% of CPE with soil application of N-P_2O_5-K_2O @ 120-90-120 kg ha^{-1}) and I_1F_2 [drip irrigation at I_1 with fertigation of same level of nutrients (F_2)] resulted in same level of maize and greater yam yields. Thus, drip irrigation saved 0.684-0.710 million litre (17.9-25.9%) of water per ha. Same level of maize and greater yam yields with the treatments control and I_2F_1/I_3F_1 also indicated a saving of nutrients N-K_2O @ 20-20 kg ha^{-1} (20%) under drip fertigation. Thus drip irrigation and fertigation not only saves water but also applied fertilizers than traditional surface flood irrigation and soil application of fertilizers.

Considering water and fertilizer use efficiency and response the treatment I_2F_3 (irrigation at 100% of CPE during 1-90 DAP + at 80% of CPE during 91-270 DAP with N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1}) is recommended for greater yam+maize intercropping system.

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