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Growth and yield of maize intercropped with vegetable amaranth as influenced by irrigation and fertilization methods

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Abstract
An experiment was conducted to study the effect of liquid organic manure application and limited irrigation on growth and yield characteristics of maize + vegetable amaranth at Tamil Nadu Agricultural University, Coimbatore during 2016-2018. The experiment was laid out in randomized block design with three replications. The treatments consisted of two irrigation methods and seven fertilizations. Drip irrigation and conventional furrow were the two irrigation methods. Humic acid 3 kg ha^{-1}, fulvic acid 3 kg ha^{-1}, vermiwash 5 per cent, jeevamiritham 5 per cent and their combinations, and inorganic fertilizers were the fertilization treatments. Drip irrigation recorded superiority in almost in all growth parameters and yield of crops. Among fertilization treatments, although inorganic fertilizer recorded significant influence on all the crop characteristics, it was comparable with humic acid 3 kg ha^{-1} + fulvic acid 3 kg ha^{-1}. Among the organic manures humic acid and fulvic acid combination registered the highest yield in both years.

Keywords: Fulvic acid (FA), Humic acid (HA), Jeevamiritham, Maize, Vermiwash.

Introduction

Maize (*Zea mays* L.) is a direct staple food for millions of individuals and through indirect consumption as a feed crop, is an essential component of global food security. The sustainability of any production system requires optimum utilization of resources, and water and nutrients are the major inputs governing the yield attributes and yield. Drip irrigation system is being used on a wide variety of crops, saving water and fertilizer and giving better yield and quality (Fanish and Muthukrishnan, 2011).

The recent energy crisis and hike in the price of inorganic fertilizers, necessitate research on cost effective liquid organic manures in crop production. Jeevamiritham prepared from cow dung, urine, legume flour and jaggery contains macro nutrients, essential micro nutrients, many vitamins, essential amino acids, hormones and beneficial micro organisms (Gore and Sreenivasa, 2011). Vermiwash is a liquid fertilizer collected after the passage of water through a column of earthworm activation. It is a collection of excretory and secretory products of earthworms containing major micronutrients that are useful for plants (More et al., 2013).

Humic substances (HS) play a vital role in soil fertility and plant nutrition. Plants grown on soils which contain adequate humin, humic acid (HA), and fulvic acid (FA) are less subject to stress, healthier, produce higher yields and the nutritional quality of harvested produces is superior (Ouni et al., 2014). Keeping the above points in view the present experiment was conducted to find out the effect of liquid organic manures on yield of maize

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Table 1. Nutrient status and microbial population of liquid organic manures

Parameter	Humic acid	Fulvic acid	Vermi wash	Jeevamiritham
Total Nitrogen (%)	3.75	4.20	0.01	0.32
Total Phosphorus (%)	1.04	0.69	0.08	0.26
Total Potassium (%)	1.46	6.01	0.13	0.06
Bacteria (cfu/ml)	0	0	82.6 x 10^6	122.7 x 10^6
Fungi (cfu/ml)	0	0	10.3 x 10^4	13.4 x 10^4
Actinomycetes (cfu/ml)	0	0	5.2 x 10^2	8.4 x 10^2

intercropped with vegetable amaranth under drip and conventional irrigated conditions.

Materials and Methods

The experiment was conducted in Tamil Nadu Agricultural University (TNAU), Coimbatore during 2016-17 and 2017-18 to analyze the response of maize intercropped with vegetable amaranth under drip and conventional irrigated conditions to various liquid organic manures in comparison with inorganic fertilization. The liquid organic manures were analysed for the nutrient status and microflora following standard methodology and the results are presented in Table1.

The pre sowing soil samples collected from the experimental site were analyzed for physical and chemical characteristics and data are presented in Table 2. The experiment was laid out in randomized block design and replicated thrice. There were 14 treatment combinations consisting of 2 factors, *viz.,* irrigation methods and fertilization methods.

Table 2. Physico-chemical characteristics of the experimental fields

Particulars	Values	
	I Year	II Year
Clay (%)	34.5	35.9
Silt (%)	19.8	21.8
Fine sand (%)	19.4	17.3
Coarse sand (%)	26.3	25.0
Textural class	Sandy clay loam	Sandy clay loam
Bulk density (g cc^{-1})	1.31	1.33
Particle density (g cc^{-1})	2.23	2.31
Porosity (%)	41.25	42.42
pH	8.34	8.10
EC (dS m^{-1})	1.16	0.78
Organic carbon (%)	0.45	0.39
Available nitrogen (kg ha^{-1})	198.0	336.0
Available phosphorus (kg ha^{-1})	19.5	17.5
Available potassium (kg ha^{-1})	648.0	468.0

Following are the treatment details:

Factor I: Irrigation methods (I) *viz.,* I_1–Drip irrigation and I_2– Conventional irrigation
Factor II: Fertilization (F) *viz.,* F_1- Humic acid @ 3 kg ha^{-1}, F_2- Fulvic acid @ 3 kg ha^{-1}, F_3- Vermiwash @ 5%, F_4 - Jeevamiritham @ 5%, F_5- Humic acid @ 3 kg ha^{-1} + Fulvic acid @ 3 kg ha^{-1}, F_6- Vermiwash @ 5% + Jeevamiritham @ 5% and F_7 - Inorganic fertilizers.

Maize hybrid "CoH(M)8" was used in the experiment. Seeds (@ 20 kg ha^{-1}) were treated with *Trichoderma viride* (4g kg^{-1}), *Pseudomonas fluorescens* (10g kg^{-1}), *Azospirillum lipoferum* (600 g ha^{-1}) and *Phosphobacterium* (600 g ha^{-1}) and sown by hand dibbling at a spacing of 60 cm × 30 cm. In surface irrigation treatment, maize was sown along the sides of the ridges with vegetable amaranth on other side. Paired row planting system was adopted under drip irrigation (2 rows of maize with 60cm row spacing and 30 cm between plants. Between the two rows of maize, two rows of amaranthus were sown with 30 cm row spacing). The vegetable amaranth seeds (@ 2.5 kg ha^{-1}) were mixed with sand at 1:5 ratio and sown. Six maize plants and twenty two vegetable amaranth plants per square metre were maintained both in drip and conventionally irrigated areas.

In the case of drip irrigation (I_1) treatments the fertilizer NPK were applied through drip fertigation (Table 3) using Urea as N source, Mono Ammonuim Phosphate (MAP) as P and Muriate of potash (MOP) as K . For conventional irrigation (I_2) treatments, soil drenching of organic liquid manures and conventional method of application of fertilizers were done. Recommended dose of fertilizers (RDF)

Table 3. Fertigation schedule for maize

Crop stages	Quantity (%)		
	N	P	K
Vegetative stage (15 – 30 days)	25	25	25
Reproductive stage (30 – 60 days)	50	50	50
Maturity stage (60 – 75 days)	25	25	25
Total	100	100	100

for maize, i.e, 150:75:75 kg of NPK per ha, were applied as indicated in Table 4. Further fertilizer sources used for supplying NPK were Urea, Single Super Phosphate (SSP) and MOP respectively for inorganic fertilization in conventional irrigation. All other standard cultural practices of TNAU for field crops were followed uniformly for all the treatments (Portal TNAU Agritech, 2014).

First irrigation was given immediately after sowing.

Table 4. Fertilization schedule for conventional irrigated (I_2F_7) treatment of maize crop

Crop	Basal	I top dressing (25DAS)	II top dressing (45DAS)
Maize	25 % N	50 % N	25 % N
	100 % P_2O_5	-	25 % N
	50 % K_2O	-	50 % K_2O

Life irrigation was given on 3 DAS to saturation level. In conventional method of surface irrigation, scheduling was done to 5.0 cm depth at 0.8 IW/CPE ratio. Subsequent irrigations were given based on the pan evaporation value from USWB Class A open pan evaporimeter at an interval of 8-12 days. Irrigation through drip was scheduled once in three days based on the daily pan evaporation at the same 0.8 IW/CPE ratio.

Gap filling was done at 7 DAS and thinning was done at 10 DAS, leaving one healthy seedling per hill to maintain 100 per cent plant population in the experimental plots. Adequate prophylactic measures were taken to protect the crop from pests and diseases by organic methods. Two hand weedings were given at 20 and 45 DAS. Intercrop of vegetable amaranthus was harvested at 25 DAS.

Leaf area index (LAI) was calculated by multiplying the leaf length, width, and number of leaves with a conversion factor, 0.75 (Elashookie, 1985). The SPAD-502 (Soil and Plant Analysis Development) chlorophyll meter developed from Minolta (Minolta Ltd, Tokyo, Japan) was used for recording maize leaf chlorophyll units at 60 DAS. The harvested cobs were dried, dehusked, shelled and cleaned separately. After cleaning, the grains were sun dried to 14 per cent moisture content. Grain weight of each treatment plot was recorded and expressed in kg ha^{-1}.

Results and Discussion

Effect of irrigation and fertilization methods on growth characters of Maize

Plant height is a direct index to assess the growth and vigour of the plant. It was found to be influenced both by irrigation method and fertilization (Table 5). Among the irrigation methods, drip irrigation showed superiority over conventional irrigation in the first year of experimentation but they were

Table 5. Plant height of maize at 60 DAS as affected by irrigation and fertilization methods

Treatments	I year			II year		
	I_{1Drip}	$I_{2Conventional}$	Mean	I_{1Drip}	$I_{2Conventional}$	Mean
F_1 - Humic acid 3 kg ha^{-1}	178.03	168.46	173.24	196.03	190.27	193.15
F_2 - Fulvic acid 3 kg ha^{-1}	168.73	168.18	168.45	194.57	190.00	192.28
F_3 - Vermiwash 5%	163.11	159.04	161.07	175.11	168.77	171.94
F_4 - Jeevamiritham 5%	166.22	162.58	164.40	185.53	169.10	177.32
F_5- Humic acid 3 kg ha^{-1}+Fulvic acid 3 kg ha^{-1}	192.81	191.34	192.07	221.70	202.87	212.28
F_6 - Vermiwash 5% + Jeevamiritham 5%	189.33	179.71	184.52	202.57	196.13	199.35
F_7 - Inorganic fertilizers	201.10	198.47	199.79	238.84	230.07	234.45
Mean	179.90	175.40	177.65	202.05	192.46	197.25
	I	F	I X F	I	F	I X F
SEd	1.575	2.947	4.167	7.099	13.281	18.783
CD(0.05)	3.197	5.982	NS	NS	27.301	NS

Table 6. LAI of maize at 60 DAS as affected by irrigation and fertilization methods

Treatments	I year			II year		
	I_{1Drip}	$I_{2Conventional}$	Mean	I_{1Drip}	$I_{2Conventional}$	Mean
F_1 - Humic acid 3 kg ha^{-1}	4.94	4.71	4.82	4.66	4.64	4.65
F_2 - Fulvic acid 3 kg ha^{-1}	4.72	4.68	4.70	4.40	4.73	4.56
F_3 - Vermiwash 5%	4.64	4.32	4.48	3.51	4.33	3.92
F_4 - Jeevamiritham 5%	4.82	4.48	4.65	4.55	4.83	4.69
F_5- Humic acid 3 kg ha^{-1} + Fulvic acid 3 kg ha^{-1}	5.20	4.89	5.04	5.09	4.97	5.03
F_6 - Vermiwash 5% + Jeevamiritham 5%	4.77	4.54	4.66	4.96	4.79	4.88
F_7 - Inorganic fertilizers	5.46	5.37	5.42	5.36	5.17	5.27
Mean	4.94	4.71	4.82	4.65	4.78	4.71
	I	F	I X F	I	F	I X F
SEd	0.108	0.201	0.284	0.168	0.314	0.444
CD(0.05)	0.218	0.408	NS	NS	0.637	NS

comparable in the second year. In the case of fertilization, all the sources of nutrients exerted marked influence on maize plant height at 60 days after sowing (DAS) and superiority was observed under inorganic fertilization (F_7) in both years. It was comparable with humic acid 3 kg ha^{-1} + fulvic acid 3 kg ha^{-1} (F_5) in the second year. Increased plant height due to humic substances application has also been reported in maize by Eyheraguibel et al. (2008). The interaction effect of irrigation method with fertilization was non significant on the plant height.

Leaf area index (LAI) is the main determining factor for light interception, affecting transpiration, photosynthesis and dry matter accumulation. The effect on LAI was similar to that on plant height indicating significant difference in method of irrigation in both years, but with increase in LAI in the case of conventional irrigation (Table 6). Regarding fertilization, significant variations were noticed in the second year only. The inorganic fertilization treatment showed the highest LAI at 60 DAS. However, it was on par with humic acid 3 kg ha^{-1} + fulvic acid 3 kg ha^{-1}(F_5), vermiwash 5 per cent + jeevamiritham 5 per cent (F_6) and humic acid alone @ 3 kg ha^{-1} (F_1). Daur and Bakhashwain (2013) have reported that humic acid application improves LAI of fodder maize. Leaf expansion due to the presence of growth regulators such as IAA, auxin etc. in humic substances might have enhanced LAI. HS enhanced plant growth by providing substances called 'auximones' (Nardi et al., 2002). The interaction between the irrigation methods and fertilization methods was not prominent in both years.

Chlorophyll is the pigment which has the capacity to channelise the energy of sunlight into chemical energy through the process of photosynthesis. It indicates the plant nitrogen status and is an important indicator of leaf senescence. The data recorded on chlorophyll index using SPAD meter at 60 DAS are given in Table 7. Drip irrigation method exhibited significant influence on the chlorophyll index (54.85 and 52.90) over the conventional irrigation (51.85 and 50.02) during both the years. Regarding fertilization, inorganic fertilizers showed continuous impact in these two years (60.27 and 56.60) but, it was on par with the combined application of humic acid @ 3 kg ha^{-1} and fulvic acid @ 3 kg ha^{-1} in their corresponding years (58.52 and 58.45). The interaction between the irrigation method and fertilization was significant in the second year only. The combined effect of drip irrigation with inorganic fertilization showed prominent effect (I_1F_7) (58.87). But it was comparable with drip irrigation with humic acid @ 3 kg ha^{-1} plus fulvic acid @ 3 kg ha^{-1} (I_1F_5) (58.77); drip + humic acid @ 3 kg ha^{-1} only (I_1F_1) (56.93); conventional irrigation + application of humic acid @ 3 kg ha^{-1} and fulvic acid @ 3 kg ha^{-1} (I_2F_5) (58.13) and conventional irrigation plus inorganic fertilization (I_2F_7) (54.33).This might be due to the

Table 7. Chlorophyll index as affected by irrigation and fertilization methods

Treatments	I year	II year				
	I_{1Drip}	$I_{2Conventional}$	Mean	I_{1Drip}	$I_{2Conventional}$	Mean
F_1 - Humic acid 3 kg ha^{-1}	54.20	49.50	51.85	56.93	49.83	53.38
F_2 - Fulvic acid 3 kg ha^{-1}	56.50	52.50	54.50	52.83	51.67	52.25
F_3 - Vermiwash 5%	43.70	40.90	42.30	40.83	40.90	40.87
F_4 - Jeevamiritham 5%	51.67	44.43	48.05	44.23	47.77	46.00
F_5 - Humic acid 3 kg ha^{-1} + Fulvic acid 3 kg ha^{-1}	58.77	58.27	58.52	58.77	58.13	58.45
F_6 - Vermiwash 5% + Jeevamiritham 5%	58.13	57.83	57.98	57.83	47.53	52.68
F_7 - Inorganic fertilizers	61.00	59.53	60.27	58.87	54.33	56.60
Mean	54.85	51.85	53.35	52.90	50.02	51.46
	I	F	I X F	I	F	I X F
SEd	1.447	2.708	3.829	1.024	1.915	2.709
CD(0.05)	2.938	5.497	NS	2.078	3.888	5.499

fact that distribution of more N evenly during each growth stage resulted in maintenance of higher auxin level which in turn resulted in better plant growth parameters and presumably the cholorophyll content of the leaves. The results are in accordance with the findings of Nardi et al. (2002).

Effect of irrigation and fertilization methods on yield components of Maize

Grains per cob play an important role in deciding yield of maize and data on the same is presented in Table 8. It showed significant increase in drip irrigation (413 and 449) over conventional irrigation (387 and 420) in both years. In the case of fertilization, inorganic fertilization (F_7) registered the highest number of grains per cob (443 and 499) in the two years but it was on par with vermiwash 5 % + jeevamiritham 5 % (F_6) in both years and in addition, in the first year, it was comparable with fulvic acid 3 kg ha^{-1} (F_2), jeevamiritham 5 % alone (F_4) and with combined application of humic acid @ 3 kg ha^{-1} and fulvic acid @ 3 kg ha^{-1} (F_5). Anjum et al. (2011) reported that fulvic acid application improved the maize performance under drought as well as well watered conditions.

The mean data on 100 grain weight of maize are furnished in Table 9. Though drip irrigation influenced the 100 grain weight in both years, it was significant in the second year only (34.6 g) compared to the conventional irrigation (32.9 g). In the case of fertilization methods, heavier grains were found in inorganic fertilization treatment (F_7) in both years (40.6 g and 39.2 g) but it was comparable with the combination of humic acid @ 3 kg ha^{-1} with fulvic acid @ 3 kg ha^{-1} (F_5) in both years (40.3 g and 36.2 g) and with vermiwash 5 % plus jeevamiritham 5 % combination (38.9 g) in the first year. Canellas et al. (2013) also found that humic substances increased maize grain production

Table 8. Number of grains per cob as affected by irrigation and fertilization methods

Treatments		I year			II year	
	I_{1Drip}	$I_{2Conventional}$	Mean	I_{1Drip}	$I_{2Conventional}$	Mean
F_1 - Humic acid 3 kg ha^{-1}	386	382	384	440	409	424
F_2 - Fulvic acid 3 kg ha^{-1}	412	387	399	432	414	423
F_3 - Vermiwash 5%	360	352	356	412	357	385
F_4 - Jeevamiritham 5%	428	371	399	419	403	411
F_5 - Humic acid 3 kg ha^{-1} + Fulvic acid 3 kg ha^{-1}	432	398	415	456	437	447
F_6 - Vermiwash 5% + Jeevamiritham 5%	428	383	406	467	441	454
F_7 - Inorganic fertilizers	447	438	443	520	478	499
Mean	413	387	400	449	420	435
	I	F	I X F	I	F	I X F
SEd	11.8	22.1	31.3	13.1	24.5	34.6
CD(0.05)	24.0	44.9	NS	26.5	49.7	NS

Table 9. 100 grain weight (g) of maize as affected by irrigation and fertilization methods

Treatments	I year			II year		
	I_{1Drip}	$I_{2Conventional}$	Mean	I_{1Drip}	$I_{2Conventional}$	Mean
F_1 - Humic acid 3 kg ha^{-1}	37.5	36.5	37.0	33.8	32.2	33.0
F_2 - Fulvic acid 3 kg ha $^{-1}$	36.4	35.9	36.1	34.4	33.6	34.0
F_3 - Vermiwash 5%	35.4	33.3	34.4	30.8	26.5	28.7
F_4 - Jeevamiritham 5%	36.6	37.0	36.8	31.8	29.3	30.5
F_5 - Humic acid 3 kg ha^{-1} + Fulvic acid 3 kg ha^{-1}	40.4	40.3	40.3	35.9	36.6	36.2
F_6 - Vermiwash 5% + Jeevamiritham 5%	38.3	39.5	38.9	34.9	33.9	34.4
F_7 - Inorganic fertilizers	41.0	40.3	40.6	40.5	37.9	39.2
Mean	37.9	37.5	37.7	34.6	32.9	33.7
	I	F	I X F	I	F	I X F
SEd	0.92	1.72	2.42	0.67	1.25	1.78
CD(0.05)	NS	3.48	NS	1.36	2.55	NS

up to 65 per cent under field conditions.

Grain yield of maize was significantly influenced by both irrigation method and fertilization factor in these two years of experimentation (Table 10). During 2017 and 2018, drip irrigation significantly increased the grain yield (6014 and 6019 kg ha^{-1}) than conventional irrigation (5597 and 5460 kg ha^{-1}). Inorganic fertilization (F_7) showed prominent impact over all the other nutrient sources in both years (7298 and 7384 kg ha^{-1}). It was followed by humic acid 3 kg ha^{-1} + fulvic acid 3 kg ha^{-1} (F_5) treatment in both years (6630 and 6227 kg ha^{-1}) and this was comparable with vermiwash 5% + jeevamiritham 5% (F_6) treatment (6250 and 6184 kg ha^{-1}) in these two years and further comparable with fulvic acid 3 kg ha^{-1} (F_2) treatment (5542 kg ha^{-1}) and humic acid 3 kg ha^{-1} (F_1) treatment (5308) in the second year of the experimentation. Similar findings on humic substances were observed by Sarir et al. (2005) on the addition of 200 g ha^{-1} HA as soil spray increasing 28 per cent grain yield (4508 kg ha^{-1}), 23 per cent total dry matter yield (10793 kg ha^{-1}) and 25 per cent total cob weight (5509 kg ha^{-1}) as compared to control (non addition of HA). No interaction effect was noticed due to the irrigation methods with fertilization on the grain yield.

Effect of irrigation and fertilization methods on yield of vegetable amaranth

The data recorded on fresh weight of vegetable amaranth are given in Table 11. Drip irrigation method recorded significantly higher yield, (4140 and 2982 kg ha^{-1}) over the conventional irrigation (3787 and 2685 kg ha^{-1}) during both years. Regarding fertilization, inorganic fertilizers showed superiority during the two years (4501 and 3645 kg ha^{-1}) but, it was comparable to the application of jeevamiritham @ 5 per cent in the corresponding

Table 10. Grain yield (kg ha^{-1}) of maize as affected by irrigation and fertilization methods

Treatments	I year			II year		
	I_{1Drip}	$I_{2Conventional}$	Mean	I_{1Drip}	$I_{2Conventional}$	Mean
F_1 - Humic acid 3 kg ha^{-1}	5440	4936	5188	5643	4973	5308
F_2 - Fulvic acid 3 kg ha $^{-1}$	5706	5231	5468	5757	5326	5542
F_3 - Vermiwash 5%	5057	4607	4832	5056	3719	4387
F_4 - Jeevamiritham 5%	5041	4897	4969	5376	4917	5146
F_5 - Humic acid 3 kg ha^{-1} + Fulvic acid 3 kg ha^{-1}	6914	6346	6630	6481	5974	6227
F_6 - Vermiwash 5% + Jeevamiritham 5%	6454	6046	6250	6397	5970	6184
F_7 - Inorganic fertilizers	7482	7114	7298	7425	7343	7384
Mean	6014	5597	5805	6019	5460	5740
	I	F	I X F	I	F	I X F
SEd	169.5	317.1	448.4	244.8	458.0	647.7
CD(0.05)	344.0	643.7	NS	496.9	929.7	NS

Table 11. Fresh yield of vegetable amaranth (kg ha^{-1}) as affected by irrigation and fertilization methods

Treatments	I year			II year		
	I_{1Drip}	$I_{2Conventional}$	Mean	I_{1Drip}	$I_{2Conventional}$	Mean
F_1 - Humic acid 3 kg ha^{-1}	4015	3343	3679	2574	2367	2471
F_2 - Fulvic acid 3 kg ha $^{-1}$	4162	4002	4082	2601	2352	2477
F_3 - Vermiwash 5%	3800	2386	3093	2458	2426	2442
F_4 - Jeevamiritham 5%	4030	4476	4253	3253	3190	3221
F_5 - Humic acid 3 kg ha^{-1} + Fulvic acid 3 kg ha^{-1}	4319	3931	4125	3086	2260	2673
F_6 - Vermiwash 5% + Jeevamiritham 5%	4160	3865	4012	3240	2574	2907
F_7 - Inorganic fertilizers	4495	4506	4501	3663	3628	3645
Mean	4140	3787	3964	2982	2685	2834
	I	F	I X F	I	F	I X F
SEd	150.3	281.2	397.6	81.6	152.7	215.9
CD(0.05)	308.9	578.0	817.4	167.7	313.9	NS

years (4253 and 3221 kg ha^{-1}). The interaction between the irrigation method and fertilization was significant in the first year only. According to Gore and Sreenivasa (2011), Jeevamiritham will promote biological activity in soil and as a result the nutrient availability to the crop will be improved.

From the results, it can be concluded that drip irrigation produced better results in terms of yield attributes and yield of maize and herbage yield of amaranthus. Regarding effect of fertilizers and manures, even though the inorganic fertilizers gave higher yield, the liquid organic manures especially the combination of humic acid 3 kg ha^{-1} along with fulvic acid 3kg ha^{-1}, were comparable to it in terms of higher number of grains per cob, hundred grain weight and grain yield. For a foliage crop like vegetable amaranth, application of jeevamiritham was observed to be more beneficial than other liquid manures.

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