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Effect of crop combination and nutrient management on yield, nutrient uptake and economics of sweet corn based cropping system

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ABSTRACT

A field experiment was conducted in rainfed upland at Bhubaneswar, Odisha during 2017-18 to study the effect of crop combinations and nutrient management practices on sweet corn (Zea mays var. saccharata) based cropping systems. The experiment was laid out in a split- plot design with three replications. Four cropping systems namely, C_1 [rice (Oryza sativa L.)-horsegram (Macrotyloma uniflorum (L.) Verdc.)], C_2 [sweet corn- horsegram], C_3 [sweet corn + black gram (Vigna mungo L.) in 2:2-horsegram] and C_4 [sweet corn + cowpea (Vigna unguiculata L.) in 2:2-horsegram] were allotted to the main-plots and three nutrient management practices i.e., N 1 (RDF), N 2 (soil test based 75% RDN + 25% N from FYM + lime 0.2 LR + biofertilizers consortium) and N 3 (FYM, vermicompost and neem oil cake to supply 1/3 rd RDN each + biofertilizers consortium) to the sub-plots. Cropping systems did not affect the growth parameters, yield, yield attributes and quality parameters of sweet corn, though the sole crop registered numerically higher values of green cob yield (7.41 t ha $^{-1}$). Integrated administration of nutrients resulted in higher growth attributes, yield, yield parameters and quality aspects of sweet corn when compared to chemical and organic nutrient package. Nutrient uptake was maximum in sweet corn + cowpea-horsegram system (123.9 kg N, 92.5 kg P and 161.8 kg K ha^{-1}) and INM practice (130.8 kg N, 55.0 kg P and 158.0 kg K ha^{-1}). Sweet corn + cowpea (2:2)-horsegram system under INM practice produced the highest system yield of 12.20 t SEY ha $^{-1}$ with BCR of 2.18.

***Keywords*: Cropping system, nutrient uptake, STBFR, sweet corn and system equivalent yield**

Food shortage and escalating food prices are serious global issues with social political and economic implications. India's food, nutritional, livelihood and economic security continues to be predicted by the performance of agricultural sector. There has been consistent production of more food to keep pace with the ever increasing population growth.Productivity of rice-rice cropping system is declining owing to several edaphic problems such as acidity, toxicity of iron, aluminium and manganese. Rapid spread of rice-wheat system has caused an unfavourable effect on sustainability of soil productivity. Maize or corn (*Zea mays* L.), the queen of cereals, now is the most important global cereal in terms of productionreflecting its versatility in use, including human food, animal feed and fodder, industrial products and bio fuel. Growing demand from poultry sector and tightening of the world export-import market justifies replacement of rice with maize in the rice-based cropping systems (Gill *et al*., 2008). Intercropping short duration and short statured pulses such as blackgram or cowpea along with maize besides being an integral part of the integrated management (INM) practice for an exhaustive crop like maize also improves the productivity, profitability and sustainability of the system harvesting the benefits of annidation with respect to both space and time. Horsegram (*Macrotyloma uniflorum* (Lam.) Verde), Syn: *Dolichos biflorus* (L.) locally known as *kulthi* is one of the important minor, rainfed pulse crops of India. It is drought tolerant and having good nitrogen fixing ability, but receives a low priority in cropping system, soil types *etc*. In addition to the protein supplement in human diet, it has medicinal value. It also furnishes concentrated feed for cattle and domestic animals. It is grown mainly as a catch or bonus crop on residual soil moisture and soil fertility after harvest of upland and early medium duration rice. Therefore, replacing rice with aerobic crop like maize and inclusion of legumes with adoption of conservation agriculture (CA) can bring improvement in soil health, environmental quality and sustainability for future agriculture (Parihar *et al*., 2018). Integrated use of organic and inorganic fertilizers has been found to be promising in obtaining sustained crop productivity on a long term basis under modern intensive cropping besides meeting the nutrients turn over in soil-plant systems. Balanced fertilization based on soil health card on INM approach and intercropping with suitable soil recuperating pulse crop will be more remunerative than upland rice and millets and may maintain soil health and the productivity of maize based cropping system such as sweet corn-horsegram in rainfed upland

MATERIALS AND METHODS

The field experiment was conducted during 2017-18 at the Central Research Station, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha under the aegis of AICRP on Maize. The station comes under the East and South Eastern Coastal Plain Agro-climatic Zone of Odisha.The experimental field was sandy loam with organic carbon 4 g kg^{-1}, available N 104 kg ha^{-1},

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available P 23 kg ha^{-1} and available K 128 kg ha^{-1}. Soil was acidic in nature.The experiment was laid out in a Split Plot Design with three replications in fixed plots of size 24 m^2. Four cropping systems were allotted to the main-plots and three nutrient management practices to the sub-plots.

a) Main-plot

C_1: Rice - horsegram

C_2: Sweetcorn - horsegram

C_3: Sweetcorn + blackgram (2:2)-horsegram

C_4: Sweetcorn + cowpea (2:2) - horsegram

b) Sub-plot

N_1: Recommended dose of fertilisers (120-60-60 kg N-P_2O_5-K_2Oha^{-1} for maize; 60-30-30 kg for rice, 20-40-20 for blackgram and 50-25-25 kg ha^{-1} for cowpea)

N_2: 75% soil test based fertiliser recommendation (STBFR) + FYM to supply 25% RDN+ lime (0.2 LR) + biofertilisers consortium (BF) + micronutrient

N_3: Organic package (FYM + vermicompost (VC) + neem oil cake (NOC) to supply 1/3rd RDN each + biofertilizers consortium) with organic pest control

The field was ploughed by tractor drawn mould board plough to bring the soil into clod free condition. The weeds, stubbles, *etc*. were removed and the field was leveled and planked. Plots were laid out with required bunds and channels. Seeds were treated with Rhizobium culture @ 20g kg^{-1} of seeds of cowpea, blackgram and horsegram. Seeds were sown in furrows made as per the plant requirement in each plot.

Well decomposed FYM, Vermicompost, Neem oil cake and chemical fertilizers (urea, DAP and MOP) were applied as per the treatments (Table 2). N and K fertilizers were applied in two equal splits *i.e.,* as basal and at 21 days after sowing (DAS). All the P was applied as basal.

Pendimethalin @ 1.0 kg *a.i.* ha^{-1}was applied as emergence spray 1 DAS. Thinning was done around 15 DAS to maintain requisite spacing for plants. Hoeing, weeding and earthing up were done at 30 DAS. Sweet corn crop was harvested for green cob, rice, greengram and horsegram as grain and cowpea as green pod for vegetable purpose. The haulms of greengram and cowpea were incorporated in the plots before sowing of horsegram.

Total weight of fresh cobs per plot was recorded separately as per the treatmentsand converted to cob yield in t ha^{-1}. The left-over sweet corn plants were cut treatment wise from the ground level after harvest of the reproductive plant parts, dried in the field, weighed and converted to stover yield in t ha^{-1}. The rice, blackgram and horsegram crops were harvested plot wise, dried, bundled weighed and threshed. After threshing the grains/seeds were weighed and deducted from bundle weight to obtain the straw or *bhusa* yields, which were converted to kg ha^{-1}. The weight of green cowpea pods, harvested plot wise in different dates were added and converted to kg ha^{-1}.The leftover *bhusa* were weighed plot wise and also converted to kg ha^{-1}.

Cropping system studies

The value of the produce ha^{-1} of each crop was calculated as per the prevailing market price. It was divided by the value of the sweet corn per kg to get the SEY in t ha^{-1}. Sum total SEY of component crops of a system was the SEY of the system. System productivity of different sweet corn based cropping systems was obtained by dividing the system yield with 365 and was expressed in kg SEY ha^{-1} d^{-1}.

Plant analysis

The plant samples (main and by product) at harvest were used for chemical analysis to determine N, P and K content in plant parts by following standard procedures *i.e*., Micro Kjeldahl (Jackson, 1976), Vanadomolybdate (Koenig and Johnson, 1942) and Flame photometry (Black,1965) methods, respectively. The uptake of nutrients was calculated by multiplying with their yields considering 10 per cent moisture in seeds of rice, 8 per cent in blackgram and horsegram seeds, 80 per cent in kernels of sweetcorn, 85 per cent in pods of cowpea and14 per cent in their straw/stover/*bhusa*. Data collected on various observations of horsegramwere analyzed statistically by standard analysis of variance technique (ANOVA) for split-plot design (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect on system yield

Adoption of different cropping systems and nutrient management practices influenced the system yield in terms of sweet corn equivalent yield (SEY).The average system yield was 8.02 t SEY ha^{-1}. A perusal of data in the table 3 affirm that sweet corn + cowpea - horse gram system produced the highest yield of 10.42 t SEY ha^{-1}, which was at par with sweet corn + black gram-horse gram system (9.76t SEY ha^{-1}) but was 25.5 per cent higher than sweet corn-horsegram and about 2.9 times of rice-horse gram system. Integrated usage of soil test based 75% RDN and 25% N through FYM along with 0.2 LR lime and biofertilisers consortium recorded the highest system yield of 9.18 t SEY ha^{-1}, being16 and 32 per cent more than RDF through inorganic sources and organic practice, respectively (Table 3).

Interaction between cropping systems and nutrient management practices rendered significant difference to the system yield. Sweet corn + cowpea (2:2)-horsegram system produced higher system yield than other systems

Table 1: Crop details

Crop	Variety	Crop duration (days)	Spacing	Seed rate (kg ha^{-1})
Sweetcorn	Sugar 75- hybrid	75	60 x 25 cm	05
Rice	Mandakini	110	20 cm line spacing	80
Blackgram	Prasad	85	30 x 10 cm	25
Cowpea	KasiKanchan	60	30 x 10 cm	50
Horsegram	Urmi	110	30 x 10 cm	30

Table 2: Fertilization details

Treatments		Urea (kg ha^{-1})	DAP (kg ha^{-1})	MOP (kg ha^{-1})	FYM (t ha^{-1})	VC (t ha^{-1})	NOC (kg ha^{-1})	Lime (kg ha^{-1})	BF
T_1	C_1N_1	104	65	50	-	-	-	-	-
T_2	C_1N_2	102	49	50	3.9	-	-	500	4(1:1:1)
T_3	C_1N_3	-	-	-	4.1	1.3	400	-	4(1:1:1)
T_4	C_2N_1	210	130	100	-	-	-	-	-
T_5	C_2N_2	206	98	100	7.7	-	-	500	4(1:1:1)
T_6	C_2N_3	-	-	-	8.3	2.6	800	-	4(1:1:1)
T_7	C_3N_1	215	174	117	-	-	-	-	-
T_8	C_3N_2	214	130	117	8.5	-	-	500	4(1:1:1)
T_9	C_3N_3	-	-	-	9	2.8	866	-	4(1:1:1)
T_{10}	C_4N_1	217	184	142	-	-	-	-	-
T_{11}	C_4N_2	210	139	142	8.6	-	-	500	4(1:1:1)
T_{12}	C_4N_3	-	-	-	9.2	2.9	883	-	4(1:1:1)

Table 3: Effect of cropping systems and nutrient management practices on system yield of sweet corn based cropping systems

Particular	System yield (tSEYha^{-1})	System productivity (kg SEY ha^{-1} d^{-1})
Cropping system		
C_2: Rice-horse gram	3.61	9.89
C_2: Sweet corn-horsegram	8.30	22.73
C_3: Sweet corn+black gram-horsegram	9.76	26.73
C_4: Sweet corn+cowpea-horsegram	10.42	28.56
SEm (±)	0.189	-
CD (0.05)	0.67	-
Nutrient management		
N_1: 100% RDF	7.91	21.67
N_2: 75% RDN + 25% RDN (FYM) + Lime 0.2 LR + biofertilisers consortium	9.18	25.16
N_3: FYM, VC and NOC to supply 1/3rd RDN each + biofertilizers consortium	6.97	19.10
SEm (±)	**0.138**	**-**
LSD (0.05)	**0.40**	**-**
Mean	**8.02**	**22.00**

Table 4: Interaction effect of cropping systems and nutrient management practices on system yield of sweet corn based cropping systems

Particular	N1: Inorganic	N2: INM	N3: Organic	Mean
C_2: Rice-horse gram	3.65	3.94	3.24	**3.61**
C_2: Sweet corn-horse gram	8.20	9.42	7.27	**8.30**
C_3: Sweet corn+black gram-horsegram	9.54	11.16	8.57	**9.76**
C_4: Sweet corn+cowpea-horsegram	10.23	12.21	8.81	**10.42**
Mean	**7.91**	**9.18**	**6.97**	**8.02**
	CS	**N**	**CS within N**	**N within CS**
SEm (±)	**0.189**	**0.138**	**0.293**	**0.276**
LSD (0.05)	**0.67**	**0.40**	**0.92**	**0.81**

at all the nutrient management practices, but was at par withsweet corn + blackgram-horsegram system under INM practice. Sweet corn + cowpea (2:2)-horsegram system under INM practice (soil test based 75% RDN and 25% N through FYM along with 0.2 LR lime and biofertilisers consortium) produced the highest system yield of 12.20 t SEY ha^{-1}. All the sweet corn based cropping systems produced higher system yields under INM practice followed by inorganic and organic package in sequence. The differences between the latter two treatments were also significant for all the systems. On the contrary, rice-horsegram produced at par system yields at all the three nutrient management practices *i.e.*, 3.94, 3.65 and 3.24 t SEY ha^{-1}under INM, inorganic and organictreatment, respectively. System productivity of sweet corn + cowpea (2:2)-horsegram system was the maximum (28.56 kg SEY ha^{-1} day^{-1}) followed by sweet corn + blackgram (2:2)-horsegram system (26.73 kg SEY ha^{-1} day^{-1}). INM practice exhibited the highest system productivity (25.16 kg SEY ha^{-1} day^{-1}) followed by 100% RDF (21.67 kg SEY ha^{-1} day^{-1}). System yield of sweet corn + cowpea- horsegram (10.42 t SEY ha^{-1}) was at par with that of sweet corn intercropped with blackgram and succeeded by horsegram (9.76 t SEY ha^{-1}) but was 25.5 per cent higher than sweet corn-horsegram and about 2.9 times of rice-horsegram system. Inclusion of leguminous crops like cowpea and blackgram as intercrop with one exhaustive crop like sweet corn has additive effect over the yield of base crop as well as succeeding crop. It enhances the productivity, profitability and sustainability of a system (Kachroo *et al.,* 2014).Residue incorporation resulted in higher organic carbon and better residual soil fertility that enhanced microbial population providing more favourable condition for the successive crop leading to higher productivity of the system as a whole .INM fared better results than 100% RDF and 100% organic treatments due to addition of FYM as an auxiliary source with 75% RDN leading to adequate supply of nutrients, higher uptake and recovery of applied nutrients. Organic manure in general and FYM in particular boost the crop yield by reducing the fixation or precipitation of nutrients in the soil (Prakasha *et al.*,2010). Moreover, liming has an ameliorative effect in a strongly acidic soil with pH 4.7 creating conducive environment for pH sensitive crops like maize and pulses.

Nutrient uptake

Data related to uptake of nutrients by the cropping systems are elucidated in table 5 which supports the facts that cropping systems and nutrient management practices affect the uptake of nutrients in the main as well as by-product and the total thereof. Among the crop combinations, the maximum total uptake of nutrients was in sweet corn+cowpea-horsegram system *i.e.,* 123.9 kg N, 92.5 kg P and 161.8 kg K ha^{-1}. Integral usage of soil test based 75% RDN in addition to 25% N through FYM, 0.2 LR lime and biofertilisers consortium resulted in the maximum nutrient uptake of 130.8kg N, 55.0 kg P and 158.0 kg K ha^{-1}, which were, respectively, 28.4, 7.8 and 22.4 kg higher than inorganic and 58.5, 22.2 and 67.5 kg more than organic practice.

On an average, 51, 68 and 88 per cent of total uptake of N, P and K by different systems was through the by-product. The percentage was less in rice-based (31-39-84) than sweet corn-based (52-76-88) systems and in INM (55-66-88) and inorganic (52-70-88) nutrition than the organic package (44-68-86).The pattern of total nutrient uptake (Table 5) almost followed the trend of the system yields (Table 3), as nutrient uptake is the function of yield and nutrient concentration, out of which yield is the main deciding factor. The highest uptake of N (130.8 kg ha^{-1}) was noticed in the INM practice in accordance with Bisht *et al*. (2013). The relevant reason might be the addition of organic manure with 75% RDN. The latter contributes as a quick source of nutrients within a short period of time, whereas the former retains the nutrients in forms that can be easily taken up by the plants over a long period of time.Similarly, due to relatively higher root distribution and stimulation by

Table 5: Effect of cropping systems and nutrient managements practices on nutrient uptake

Particular	Nutrient uptake by the system (kg ha^{-1})								
	N			P			K		
	Main Product	By-product	Total	Main Product	By-product	Total	Main Product	By-product	Total
Cropping system									
C_1: Rice-horsegram	50.2	23.3	75.5	9.8	6.2	16	12.2	64.8	77
C_2: Sweet corn-horsegram	32.5	63.1	95.6	8.9	22.3	31.2	13.6	119.8	133.3
C_3: Sweet corn+black gram-horse gram	55.8	58.2	114	9.7	30.6	40.2	17	123.2	140.2
C_4: Sweet corn+cowpea-horse gram	60.7	63.1	123.9	29.2	63.3	92.5	20.4	141.4	161.8
SEm (±)	**0.98**	**0.66**	**1.41**	**0.30**	**1.19**	**1.12**	**0.26**	**2.90**	**2.88**
LSD (0.05)	**3.40**	**2.30**	**4.90**	**1.10**	**4.10**	**3.90**	**0.90**	**10.0**	**10.00**
Nutrient management									
N_1: 100% RDF	49.5	52.9	102.4	14.2	33	47.2	15.8	119.8	135.6
N_2: 75% RDN + 25% RDN (FYM) + Lime 0.2 LR + biofertilisers consortium	59.6	71.3	130.8	18.5	36.5	55	19.1	139	158
N_3: FYM, VC and NOC to supply 1/3rd RDN each + biofertilizers consortium	40.4	31.6	72	10.5	22.3	32.8	12.5	78	90.5
SEm (±)	**0.92**	**1.11**	**1.43**	**0.31**	**1.24**	**1.21**	**0.27**	**2.08**	**2.06**
LSD (0.05)	**2.70**	**3.24**	**4.17**	**0.90**	**3.60**	**3.50**	**0.80**	**6.10**	**6.00**
Mean	**49.8**	**51.9**	**101.7**	**14.4**	**30.6**	**45**	**15.8**	**112.3**	**128.1**

Table 6: Effect of cropping systems and nutrient management practices on economics of sweet corn based cropping systems

Particular	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	BCR
Cropping system				
C_1: Rice-horsegram	53,381	54,152	771	1.08
C_2: Sweet corn-horsegram	73,095	1,24,431	51,336	1.96
C_3: Sweet corn + black gram-horsegram	72,656	1,46,355	73,700	2.17
C_4: Sweet corn + cowpea-horsegram	82,309	1,56,373	74,064	2.18
Nutrient management				
N_1: 100% RDF	50,082	1,18,655	68,573	2.31
N_2: 75% RDN + 25% RDN (FYM) + Lime 0.2 LR + biofertilisers consortium	59,877	1,37,730	77,853	2.23
N_3: FYM, VC and NOC to supply 1/3rd RDN each + biofertilizers consortium	1,01,121	1,04,598	3477	1.01
Mean	**70,360**	**1,20,328**	**49,968**	**1.85**

microorganisms (Arancon *et al*., 2005), there was better absorption of water and nutrients from the lower layers of soil horizon which resulted in higher yield and nutrient uptake of P by INM practice. Biofertilizers are known to synthesize various complex compounds and release nutrients to the rhizosphere. They secret growth promoting substances like IAA, gibberlic acid, cytokinin, *etc*, which modify root morphology, increase nutrient use efficiency and produce organic acids that improve availability of P and other nutrients (Pattanayak *et al*., 2007), thereby, increasing P content in plant parts and their uptake. Due to synergistic effect of N, activity of microbes around the rhizosphere and enhanced number of root hairs, K uptake also followed the same trend as that of N uptake (Hammad *et al*.,2011).Higher uptake of N, P and K in INM was perhaps due to more dry matter production by crops and less nutrient depletion due to better nutrient management through INM and subsequently more availability of nutrients to the successive crop.Other studies also suggested that the presence of organic residues on surface induced more root growth and resulted in increased removal of nutrients by crops. The total uptake of nutrients was higher in sweet corn+ cowpea- horsegram, sweet corn+ black gram- horsegram and sweet corn- horsegram in order mostly because of higher system yield.

The cost of cultivation for the cropping systems under different nutrient management practices ranged from Rs. 41,138 to Rs. 1,23,590 ha^{-1}with the average of Rs. 70,360 ha^{-1}. Sweet corn + cowpea-horsegram system required the highest investment (Rs.82,309 ha^{-1}) followed by sweet corn + blackgram-horsegram system (Rs.72,656 ha^{-1}). Rice-horsegram system incurred the least expenditure of Rs 53,381ha^{-1}. The cost of cultivation was maximum with organic nutrition *i.e*., Rs. 1,01,121 ha^{-1}as compared to Rs. 59, 877 and 50,082 ha^{-1}under INM and inorganic nutrition, respectively.Sweet corn + cowpea-horsegram system fetched the highest gross (Rs.1,56,373 ha^{-1}) and net (Rs.74,064 ha^{-1}) returns followed by sweet corn + blackgram-horsegram, sweet corn-horse gram and rice-horse gram (Rs.54,152 and Rs. 771 ha^{-1})system. Integrated nutrient management retrieved gross returns of Rs. 1,37,730 ha^{-1} and net returns of Rs.77,853 ha^{-1}, which were Rs. 19, 075 and Rs.9280 more than the inorganic practice of 100% RDF. The lowest gross (Rs. 1,04,598 ha^{-1}) and net (Rs. 3477 ha^{-1}) returns were obtained from the organic fertilization practice.Sweet corn intercropped with cowpea or blackgram followed by horsegram in the sequence registered higher BCR of 2.18 (Table 6) than sweetcorn-horsegram (1.96) or rice-horsegram (1.08) systems. The BCR was maximum (2.31) with 100% RDF in inorganic form followed by INM practice (2.23) and was the minimum in organic treatment (1.01). Due to higher system yield in sweet corn+ cowpea- horsegram and sweet corn + black gram- horsegram systems, they fetched the highest gross and net returns as well as BCR (Table 6). Rice-horsegram system incurred the least cost and also fetched the lowest income. The investment was maximum with the organic package because of higher price of organic sources per unit nutrient (Singh *et al*., 2007). As the system as a whole and component crops as a whole incurred a higher yield, INM package of practice proved to be economically efficient over 100% RDF and 100% organics. The monetary returns were minimum with organic package because of higher cost of cultivation in one end and lower yield as well as lack of prime price for the organic produce at the other.

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