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Research Article
Assessment of Sweetcorn Hybrids Under Sweetcorn/Chilli Pepper Intercropping in West Java, Indonesia

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Abstract
Objective: Sweetcorn/chilli pepper intercropping is commonly applied to increase yield and profit by farmers in West Java, Indonesia. **Methodology:** An experiment was set up in Kutamandiri-Sumedang, West Java from January up to April, 2015 to select new sweetcorn hybrid and their parental lines for intercropping with chilli pepper. To evaluate the genetic materials, they were arranged by split plot design. This was replicated twice with the main plot consisting of four cropping systems, whereas, the subplots were 38 sweetcorn genotypes. **Results:** The result showed that parental line of MSR 17.2.3 is the best combiner for plant height, while SR 17 is the best combiner for maturity and ear weight per plant. The best combinations for high yield in both sole cropping and intercropping are MSR 12.6.7xSR 4 and MSR 25.5.1xSR 17. However, MSR 17.6.7xSR 17 were the best hybrid for intercropping based on land equivalent ratio, competitive ratio and stress tolerance index analysis. **Conclusion:** It is also identified that MSR 17.6.7xSR 17 was suitable for sweetcorn/chilli pepper intercropping for the following aspects including higher yield than sweetboy check variety both in sole and intercropping system, moderately level of competition ratio against chilli pepper, low tolerance index to chilli pepper and higher productivity in 2:1 sweetcorn/chilli pepper intercropping system.

Key words: Competitive ratio, land equivalent ratio, stress tolerance index, sweetcorn/chilli pepper intercropping

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Sweetcorn and chilli pepper are two important horticulture products, which could be cultivated either in sole cropping system or in intercropping system[1,2]. Sweetcorn is an alternative food instead of rice, baby's food, agro industrial product for ethanol and high fructose corn syrup, whereas chilli pepper is among the most importance spice having high economic values and among the importance spicy in Indonesia.

Management of two commodities in particular intercropping system is the right strategy that can be developed in Indonesia to increase production of the two commodities involved. The characteristic of farming system in Java island the most populated island in Indonesia, shows a dependence on lands that are small in area with poor land management and does not yield optimal results. The purpose of this planting system is to decrease the risk of harvest failure due to biotic stress. Thus, in case one crop fails to harvest good yield, the other crop can still be harvested and hopefully the loss will be less than when only one crop is planted. Midmore *et al.*[3] reported that sweetcorn/chilli pepper intercropping reduced viral infection in pepper plants. Further he mentioned the advent of sweetcorn/chilli pepper cropping system including: (i) The cropping system improved the efficiency of cropping due to the ability to catch more sunlight than by growing alone as indicated by Land Equivalent Ratio (LERs) of sweetcorn/chilli pepper greater than unity and (ii) The pepper can be benefitted if intercropped with taller plants because of wind break effects. The taller plants help reduce evapotranspiration, aphid infestation and virus spread.

Among the factors that need to be considered when determining the intercropping strategy is the kind of crop and the cultivar that will be planted[4]. The kinds of cultivars that will be planted depend upon their characteristics. The cultivars should not compete with each other so that the harvest will be maximal for each cultivar. Most of the cultivars of sweetcorn available in the market are usually grown as a single crop. In a study by O'Leary and Smith[5], they found out that when corn/clover or corn/bean intercrops are desired, corn monoculture is not desired. Also, selection in intercrops determines the genotype adapted to the other.

Plant breeding programs are very important in developing cultivars of sweetcorn that suitable into an intercropping system. According to Koutsika-Sotiriou and Karagounis[6], the choice of the genetic resources are priority in the development of cultivars specially in obtaining cultivars that have high yields according to the specific conditions. So far, it had developed corn-inbred lines by hybridization and mutation[7]. These inbred lines divers for morphological and yield components in a sole cropping system[8]. However, the information on combining ability of these inbred lines and the performance of their hybrids in sweetcorn/chilli pepper intercropping system were not yet explored.

MATERIALS AND METHODS

Genetic material and evaluation site: Genetic material to be evaluated in the study were 38 genotypes included 8 SR unpad inbred lines of sweetcorn, 28 F1 developed through diallel mating design by Griffing II and two commercial sweetcorn hybrids (Sweetboy and Jamboree). In addition unpad chilli pepper was used for sweetcorn/chilli pepper cropping system. Evaluation was performed from January up to April, 2015 in Kutamandiri, West Java, Indonesia at 784 m a.s.l. (above sea level), which represents climate type of C3 classified by Oldeman.

Statistical analysis: A split plot design was done with 2 replications to evaluate inbred lines. The intercropping systems, which consisting the main plot were sweetcorn sole cropping system, sweetcorn/chilli pepper, sweetcorn/chilli pepper/sweetcorn and chilli pepper/sweetcorn/chilli pepper; whereas, the subplots were 38 sweetcorn genotypes. The traits to be observed are plant height, maturity and ear weight per plant.

Data analysis covered estimation of combining ability and evaluation of sweetcorn hybrid in intercropping system with chilli pepper and otherwise. The ANOVA was done for the average data for split plot design. Diallel crosses were analysed based on Griffing II method[9], which estimates General Combining Ability (GCA) of sweetcorn inbred. Specific Combining Ability (SCA) was estimated to determine superior hybrids. The significance of hybrids, GCA and SCA mean squares were estimated using F test. The GGE biplot is also used for diallel cross analysis. This was done by utilizing GGE biplot software[10].

Evaluation of adaptive sweetcorn hybrid performance in intercropping with chilli pepper was estimated using least significant increase following by Petersen[11]. Thus, productivity of hybrid in intercropping with chilli pepper was determined based on Land Equivalent Ratio (LER) according to Willey[12] and competitive ratio of sweetcorn hybrid following by Dhima *et al.*[13]. On contrary to the evaluation of sweetcorn hybrid performance, evaluation of tolerant chilli pepper to sweetcorn under sweetcorn/chilli pepper cropping system was estimated based on Stress Tolerance Index (STI)[14].

RESULTS AND DISCUSSION

General and specific combining ability of sweetcorn: Table 1 shows the ANOVA testing for significance of the studied traits. The source of variation for the genotypes was divided into two: General Combining Ability (GCA) and Specific Combining Ability (SCA). Significant differences for GCA and SCA were seen in all the studied traits. This shows the importance of additive and dominance genetic variance[15].

Combining ability analysis helps assess potential inbred lines. They also help identify the kind of gene action taking place in various quantitative characters, as agronomy, yield component and yield[16-18]. Abdel-Moneam *et al.*[19] mentioned that the effects of combining ability are important indicators in determining potential inbred lines as parental of superior hybrid in maize. This implies that in determining high yield hybrids, the parents genetic structure and their combing ability play important roles. Differences in GCA effects reflected additive and epistatic genetic effects in the observed population, whereas variation in SCA effects associated to non-additive genetic variance including dominance and epistatic genetic effects[16]. Sprague and Tatum[15] proposed that GCA was relatively more important than SCA for unselected inbred lines. On the other hand, SCA played a more important role for selected lines. The values for combining ability effects showed that none of the parental line showed desirable GCA effects for all the traits studied (Table 2 and Fig. 1 and 2). Hussain *et al.*[20] and Ruswandi *et al.*[17] also observed similar results to this finding. In the present study, line b (SR 17) had the highest positive and highly significant GCA effect for grain yield. This parental line also had high mean value. This shows that the performance of the line can be useful as index for combining ability. The SR 17 and MSR 25.5.1 parental lines exhibited highest negative and significant GCA for maturity, therefore these lines are good combiners for early maturing. In addition, MSR 17.2.3 showed highest negative and significant GCA for plant height, which indicates that it is a good general combiner for this trait. In crossing programs for maximum genetic variability, it is reconsidered to use lines with desirable GCA as for synthetic cultivar development[21].

The SCA for plant height, maturity and ear weight per plant was estimated based on Griffing II and GGE biplot and they are presented in Table 3 and 4 and Fig. 1 and 2. Based on SCA estimate using Griffing II and GGE biplot (Table 3 and 4 and Fig. 1 and 2), hybrid SR 43xSR 17 showed greatest SCA for plant height, maturity and ear weight per plant. This indicated that hybrid would perform short plant, early maturity and high ear weight per plant comparing to their parents. MSR 25.5.1xSR 17 hybrid also possessed high SCA for maturity and ear weight per plant. In addition, MSR 25.2.6xMSR 17.2.3 had great SCA for ear weight per plant. Some researchers also reported high positive SCA together with a high yield performance and their component[17-22]. These hybrids showing high performance for yield and early maturity would be potentially useful in sweetcorn breeding programs to obtain high-yielding hybrids for intercropping in the same climate of West Java, Indonesia.

Evaluation of sweetcorn hybrid performance in sweetcorn/chilli pepper intercropping: Table 5 showed means of ear weight per plant from 30 sweetcorn hybrids

Table 1: Analysis of variance (ANOVA) of genotype and combining ability

Source of variations	Degree of freedom	Plant height	Days to harvest	Ear weight per plant	$F_{.05}$
Replication	35	16.63*	91.81*	3.16	4.12
Genotype	35	2.45*	12.28*	8.80*	1.76
GCA	7	3.51*	11.10*	7.70*	2.28
SCA	28	2.2*	12.57*	9.11*	1.80
Error	35				
Coefficient of variance		6.07	3.98	10.09	

*Significant based on F-test at 5%

Table 2: General Combining Ability (GCA) estimates and means of observed traits

	Plant height		Days to harvest		Ear weight per plant	
Genotypes	GCA	Mean	GCA	Mean	GCA	Mean
SR 4	6.05*	152	0.20	89	5.10	134.70
SR 17	1.15	156	**-1.10***	85	**18.21***	241.35
SR 24	-1.25	139	-0.20	85	-6.33	95.90
SR 43	-1.15	149	0.90*	89	2.84	143.70
MSR 17.2.3	**-6.95***	122	0.40*	90	-20.20*	104.41
MSR 17.6.7	0.95	132	-0.10	88	-2.83	170.70
MSR 25.2.6	2.25*	143	0.50*	86	1.66	152.55
MSR 25.5.1	-1.05	143	**-0.60***	87	4.88	188.25

*Significant based on F-test at 5%

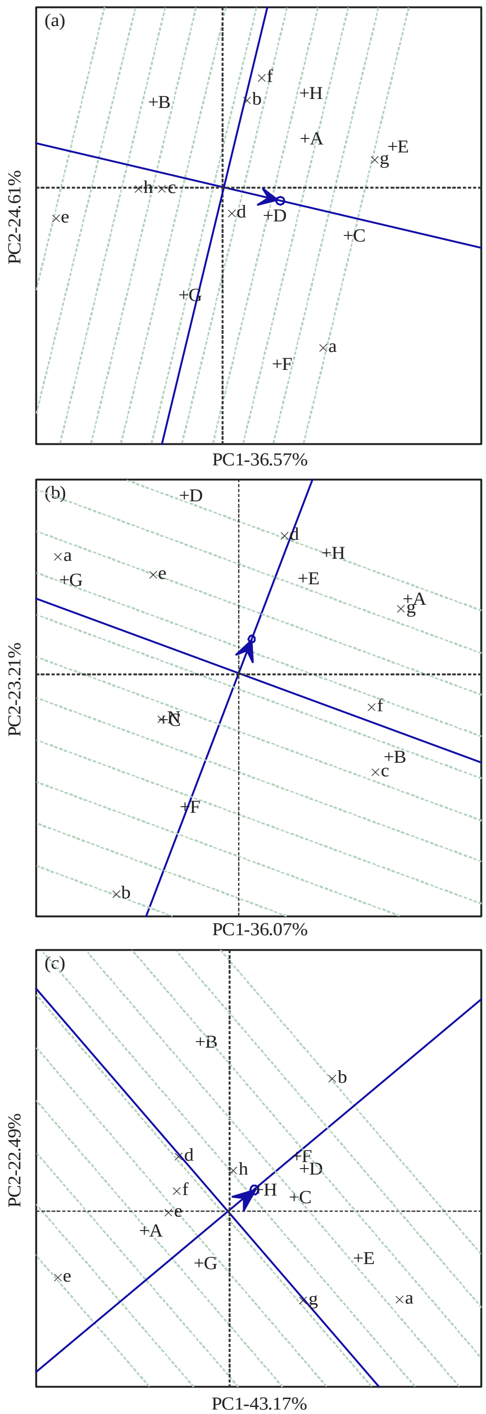

Fig. 1(a-c): Average Tester Coordination (ATC) view of the biplot based on diallel. The arrow represents the average tester. Parental lines as entry is presented as small letter, whereas parental lines as tester is showed as capital letters. A/a: SR 4, B/b: SR 17, C/c: SR 24, D/d: SR 43, E/e: MSR 17.2.3, F/f: MSR 17.6.7, G/g: MSR 25.6.7, H/h: MSR 25.5.1., (a) Plant height, (b) Maturity and (c) ear weight per plant

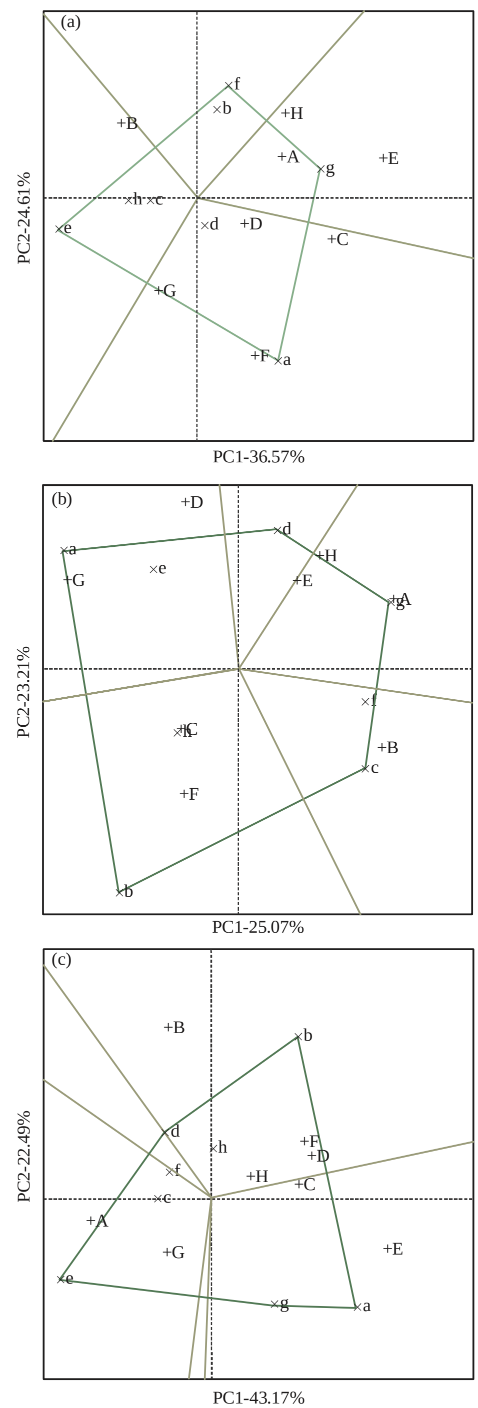

Fig. 2(a-c): Scatter plot view of the biplot based on diallel. The arrow represents the average tester. Parental lines as entry is presented as small letter, whereas parental lines as tester is showed as capital letters. A/a: SR 4, B/b: SR 17, C/c: SR 24, D/d: SR 43, E/e: MSR 17.2.3, F/f: MSR 17.6.7, G/g: MSR: 25.6.7, H/h: MSR 25.5.1., (a) Plant height, (b) Maturity and (c) Ear weight per plant

Table 3: Selected crosses based on GGE biplot and Griffing II

Traits	Selected crosses			
Plant height	axB	(SR 4xSR 17)	hxA	(MSR 25.5.1xSR 4)
	exA	(MSR 17.2.3xSR 4)	bxD	(SR 17xSR 43)
	exH	(MSR 17.2.3xMSR 25.5.1)	gxB	(MSR 25.2.6xSR 17)
	Range of SCA -16, 9-(-3, 72)			
Days to harvest	bxA	SR 17xSR 4	cxD	SR 43xSR 24
	dxB	SR 43xSR 17	gxC	MSR 25.2.6xSR 24
	bxE	SR 17xMSR 17.2.3	fxD	MSR 17.6.7xSR 43
	bxG	SR 17xMSR 25.2.6	gxF	MSR 25.2.6xMSR 17.6.7
	bxH	MSR 25.5.1xSR 17		
	Range of SCA -4.30-(-1.10)			
Ear weight per plant	exA	(MSR 17.2.3xSR 4)	hxB	(MSR 25.5.1xSR 17)
	dxB	(SR 43xSR 17)	gxE	(MSR 25.2.6xMSR 17.2.3)
	fxB	(MSR 17.6.7xSR 17)		
	Range of SCA 24.21-77.86			

Table 4: SCA and mean of days to harvest and ear weight per plant

Genotypes			Biplot codes	Days to harvest		Ear weight per plant	
				SCA	Means	SCA	Means
SR 17	X	SR 4	(bxA)	**-1.40****	86	-66.37**	132.68
SR 24	X	SR 4	(cxA)	0.10	89	5.22	183.23
SR 43	X	SR 4	(dxA)	2.30**	91	5.27	206.00
MSR 17.2.3	X	SR 4	(exA)	1.10**	89	**77.86****	238.51
MSR 17.6.7	X	SR 4	(fxA)	0.60*	90	5.58	200.10
MSR 25.2.6	X	SR 4	(gxA)	2.60**	91	5.76	198.95
MSR 25.5.1	X	SR 4	(hxA)	1.70**	90	5.16	103.85
SR 24	X	SR 17	(cxB)	0.70**	88	-0.62	190.50
SR 43	**X**	**SR 17**	(dxB)	**-3.10****	84	**24.21****	223.05
MSR 17.2.3	X	SR 17	(exB)	**-3.10****	85	-4.41	169.35
MSR 17.6.7	X	SR 17	(fxB)	2.20**	90	**34.65****	212.25
MSR 25.2.6	X	SR 17	(gxB)	**-2.20****	89	-61.75**	130.55
MSR 25.5.1	X	SR 17	(hxB)	**-1.70****	85	**35.85****	222.75
SR 43	X	SR 24	(dxC)	**-1.60****	87	-41.45**	136.35
MSR 17.2.3	X	SR 24	(exC)	1.20**	89	-33.09**	119.63
MSR 17.6.7	X	SR 24	(fxC)	0.70**	90	5.26	188.85
MSR 25.2.6	X	SR 24	(gxC)	**-4.30****	84	5.14	200.40
MSR 25.5.1	X	SR 24	(hxC)	0.80**	89	5.29	193.05
MSR 17.2.3	X	SR 43	(exD)	2.40**	90	-25.28**	135.15
MSR 17.6.7	X	SR 43	(fxD)	**-1.10****	88	5.62	118.95
MSR 25.2.6	X	SR 43	(gxD)	-0.10	88	5.13	191.10
MSR 25.5.1	X	SR 43	(hxD)	1.00**	89	-30.02**	153.45
MSR 17.6.7	X	MSR 17.2.3	(fxE)	-0.10	86	-15.27**	133.95
MSR 25.2.6	**X**	**MSR 17.2.3**	(gxE)	2.70**	90	**44.82****	198.72
MSR 25.5.1	X	MSR 17.2.3	(hxE)	0.80**	88	4.26	175.65
MSR 25.2.6	X	MSR 17.6.7	(gxF)	**-1.80****	87	6.70	174.46
MSR 25.5.1	X	MSR 17.6.7	(hxF)	3.30**	92	4.95	108.10
MSR 25.5.1	X	MSR 25.2.6	(hxG)	-0.70**	87	-11.03*	165.90

*Significant based on F-test at 5%, **Significant based on F-test at 1%

planted in different cropping system. The results from this study showed that sole cropping yielded higher than all the sweetcorn/chilli pepper intercrop. However, there were 7 sweetcorn hybrids possessing higher ear weight per plant than commercial hybrid sweetboy. Those hybrids were SR 43xSR 4, MSR 17.2.3xSR 4, SR 43xSR 17, MSR17.6.7xSR17, MSR 25.5.1xSR 17, MSR 25.2.6xSR 24 and MSR 25.5.1xMSR 17.6.7.

Land Equivalent Ratio (LER) for sweetcorn hybrids was shown in Table 6. The highest LER were in sweetcorn/chilli pepper 2:1 intercropping. There were 4 hybrids possessed LER more than 1 in intercropping sweetcorn/chilli pepper 2:1 (P 2:1) including MSR 17.6.7xSR 4 (LER 1.01), MSR 17.6.7xSR 17 (LER 1.01), SR 43xSR 24 (LER 1.04) and MSR 17.6.7xSR 43 (LER 1.02). Similar result also reported by Muraya *et al.*[23] explaining that maize/bean intercropping had high economic advantage. He studied that everton synthetic maize showing higher LER than check varieties KTS and H 614. He explained the characteristic maize for intercropping including

Table 5: Means of ear weight per plant of 30 sweetcorn hybrids

Genotypes			P1	P1:1	P2:1	P1:2	Mean
SR 17	X	SR 4	133	158	131	137	139.45
SR 24	X	SR 4	183	155	197	213	186.86
SR 43	X	SR 4	206	188	221	228	210.57S
MSR 17.2.3	X	SR 4	239	222	221	227	226.94S
MSR 17.6.7	X	SR 4	200	185	201	194	194.98
MSR 25.2.6	X	SR 4	199	164	194	198	188.64
MSR 25.5.1	X	SR 4	204	173	212	201	197.25
SR 24	X	SR 17	191	165	182	198	183.84
SR 43	X	SR 17	223	221	220	209	218.11S
MSR 17.2.3	X	SR 17	169	158	180	176	170.64
MSR 17.6.7	X	SR 17	212	198	209	227	211.26S
MSR 25.2.6	X	SR 17	131	143	150	152	143.69
MSR 25.5.1	X	SR 17	223	222	223	228	223.97S
SR 43	X	SR 24	136	173	152	164	156.17
MSR 17.2.3	X	SR 24	120	109	134	137	124.60
MSR 17.6.7	X	SR 24	189	193	174	189	186.09
MSR 25.2.6	X	SR 24	200	181	212	215	201.86S
MSR 25.5.1	X	SR 24	193	191	182	210	193.93
MSR 17.2.3	X	SR 43	135	152	155	153	148.58
MSR 17.6.7	X	SR 43	209	160	210	212	197.64
MSR 25.2.6	X	SR 43	191	165	179	203	184.18
MSR 25.5.1	X	SR 43	153	148	149	150	149.89
MSR 17.6.7	X	MSR 17.2.3	134	125	115	143	129.04
MSR 25.2.6	X	MSR 17.2.3	199	165	179	230	193.07
MSR 25.5.1	X	MSR 17.2.3	176	172	163	189	174.89
MSR 25.2.6	X	MSR 17.6.7	174	168	166	164	167.98
MSR 25.5.1	X	MSR 17.6.7	208	204	195	188	198.76S
MSR 25.5.1	X	MSR 25.2.6	166	170	197	179	177.75
Jambore			212	203	209	218	210.38
Sweetboy			176	180	176	182	178.54
Least Significant Increase (LSI)							19.53
Jambore+LSI					229.90		
Sweetboy+LSI					198.07		

P1: Sweetcorn sole planting, P1:1: Intercropping sweetcorn/chilli pepper 1:1, P2:1: Intercropping sweetcorn/chilli pepper 2:1, P1:2: Intercropping sweetcorn/chilli pepper 1:2, S: Hybrid better than commercial check hybrid sweetboy based on LSI at 5%, J: Hybrid better than commercial check hybrid Jamboree based on LSI at 5%

modification of canopy geometry and photosynthetic apparatus aside of yield and its components.

Sweetcorn hybrid adapted for intercropping with chilli pepper should be selected based on its land productivity as shown by its LER. Li *et al.*[24] explained that the LER more than one indicating the high economic advantage of particular intercropping. This intercropping index indicates that intercropping is more advantageous than sole cropping in terms of the efficiency of using environmental resources for growth or by increased plant density[25,26]. Furthermore, Willey and Reddy[27] explained that yield advantages in intercropping occurs due to differences in their use of resources and its stability greater than in sole cropping system. Evans and Wardlaw[28] reported that shading and reduced assimilate production have least effect on yield in intercropping, while competition prevails during vegetative periods.

Table 6: Land Equivalent Ratio (LER) of 30 sweetcorn hybrids in intercropping sweetcorn/chilli pepper

Genotypes			P1:1	P2:1	P1:2
SR 17	X	SR 4	0.92	0.85	0.91
2SR 24	X	SR 4	0.81	0.93	0.82
SR 43	X	SR 4	0.91	0.90	0.86
MSR 17.2.3	X	SR 4	0.82	0.76	0.83
MSR 17.6.7	X	SR 4	0.83	**1.01**	0.93
MSR 25.2.6	X	SR 4	0.83	0.84	0.86
MSR 25.5.1	X	SR 4	0.88	0.91	0.89
SR 24	X	SR 17	0.82	0.88	0.87
SR 43	X	SR 17	0.84	0.73	0.82
MSR 17.2.3	X	SR 17	0.71	0.93	0.81
MSR 17.6.7	X	SR 17	0.93	**1.01**	0.86
MSR 25.2.6	X	SR 17	0.97	0.96	0.93
MSR 25.5.1	X	SR 17	0.83	0.78	0.96
SR 43	X	SR 24	0.86	**1.04**	0.93
MSR 17.2.3	X	SR 24	0.85	0.92	0.95
MSR 17.6.7	X	SR 24	0.73	0.81	0.82
MSR 25.2.6	X	SR 24	0.79	0.90	0.89
MSR 25.5.1	X	SR 24	0.83	0.85	0.91
MSR 17.2.3	X	SR 43	0.80	0.93	0.94
MSR 17.6.7	X	SR 43	0.82	**1.02**	0.88
MSR 25.2.6	X	SR 43	0.77	0.84	0.89
MSR 25.5.1	X	SR 43	0.79	0.87	0.85
MSR 17.6.7	X	MSR 17.2.3	0.90	0.80	0.85
MSR 25.2.6	X	MSR 17.2.3	0.87	0.88	0.85
MSR 25.5.1	X	MSR 17.2.3	0.88	0.79	0.89
MSR 25.2.6	X	MSR 17.6.7	0.75	0.86	0.81
MSR 25.5.1	X	MSR 17.6.7	0.87	0.87	0.77
MSR 25.5.1	X	MSR 25.2.6	0.95	0.96	0.95
Jambore			0.79	0.74	0.81
Sweetboy			0.84	0.88	0.88

P1: Sweetcorn sole planting, P1: 1: Intercropping sweetcorn/chilli pepper 1:1, P2:1: Intercropping sweetcorn/chilli pepper 2:1, P1:2: Intercropping sweetcorn/chilli pepper 1:2

Some researchers also showed similar LER value exceeding one when they applied maize intercropping. Some maize based intercropping includes maize/bush bean[29], maize/cowpea[30], maize/dwarf bean[31], cereal/legume intercropping[32], legume/cereal intercropping[33] and maize/soybean intercropping[34,35].

Competitive ratio of sweetcorn hybrids cultivated in sweetcorn/chilli pepper intercropping system: The competition between sweetcorn and chilli pepper in intercropping was predicted by Competitive Ratio (CR) index and is presented in Table 7. The result showed that CR sweetcorn/chilli pepper (CRj) was higher than CR chilli pepper/sweetcorn (CRc) in all-intercropping system. This indicated that sweetcorn hybrids have higher competitiveness than chilli pepper and this is the reason why sweetcorn hybrid is stable under different intercropping pattern with chilli pepper. The CR sweetcorn/chilli pepper was greater than 1.00 but CR chilli pepper/sweetcorn was less than 1.00 suggesting that chilli pepper is a mild competitor and it is suitable crop in

Table 7: Competitive Ratio (CR) of 30 sweetcorn hybrids in intercropping sweetcorn/chilli pepper

Genotypes			P1:1		P2:1		P1:2	
			CRj	CRc	CRj	CRc	CRj	CRc
SR 17	X	SR 4	1.25	0.80	1.68	0.60	1.23	0.82
SR 24	X	SR 4	1.29	0.77	1.66	0.61	1.82	0.56
SR 43	X	SR 4	1.33	0.76	1.97	0.52	1.50	0.67
MSR 17.2.3	X	SR 4	1.55	0.65	2.06	0.51	1.23	0.81
MSR 17.6.7	X	SR 4	1.18	0.86	**0.99**	**1.01**	1.06	0.94
MSR 25.2.6	X	SR 4	1.23	0.82	1.73	0.59	1.26	0.80
MSR 25.5.1	X	SR 4	1.34	0.76	1.60	0.63	1.18	0.86
SR 24	X	SR 17	1.62	0.62	1.32	0.76	1.34	0.75
SR 43	X	SR 17	1.33	0.76	3.01	0.44	1.28	0.81
MSR 17.2.3	X	SR 17	1.40	0.77	1.67	0.62	1.56	0.68
MSR 17.6.7	X	SR 17	1.18	0.85	**0.92**	**1.08**	1.42	0.71
MSR 25.2.6	X	SR 17	1.40	0.72	2.11	0.50	1.42	0.70
MSR 25.5.1	X	SR 17	1.39	0.72	1.50	0.68	1.10	0.91
SR 43	X	SR 24	1.79	0.56	1.27	0.80	1.55	0.66
MSR 17.2.3	X	SR 24	1.59	0.63	2.31	0.47	1.33	0.75
MSR 17.6.7	X	SR 24	2.11	0.57	1.62	0.64	1.42	0.73
MSR 25.2.6	X	SR 24	1.94	0.57	1.83	0.57	1.33	0.75
MSR 25.5.1	X	SR 24	1.57	0.64	1.55	0.71	1.33	0.75
MSR 17.2.3	X	SR 43	2.39	0.45	2.30	0.43	1.33	0.75
MSR 17.6.7	X	SR 43	1.26	0.82	**0.95**	**1.05**	1.25	0.80
MSR 25.2.6	X	SR 43	2.59	0.50	2.09	0.56	1.55	0.73
MSR 25.5.1	X	SR 43	1.35	0.75	1.68	0.62	1.33	0.78
MSR 17.6.7	X	MSR 17.2.3	2.93	0.57	1.64	0.63	1.72	0.64
MSR 25.2.6	X	MSR 17.2.3	2.72	0.60	1.51	0.77	2.06	0.57
MSR 25.5.1	X	MSR 17.2.3	1.99	0.61	2.91	0.38	1.63	0.71
MSR 25.2.6	X	MSR 17.6.7	2.76	0.38	2.35	0.58	1.50	0.74
MSR 25.5.1	X	MSR 17.6.7	1.47	0.69	1.52	0.71	1.40	0.77
MSR 25.5.1	X	MSR 25.2.6	1.37	0.73	2.32	0.44	1.22	0.82
Jambore			1.93	0.63	1.35	0.74	1.71	0.65
Sweetboy			1.54	0.65	1.67	0.60	1.34	0.76

P1: Sweetcorn sole planting, P1: 1: Intercropping sweetcorn/chilli pepper 1:1, P2: 1: Intercropping sweetcorn/chilli pepper 2:1, P1: 2: Intercropping sweetcorn/chilli pepper 1:2. CRj: Competitive ratio sweetcorn/chilli pepper, CRc: Competitive ratio chilli pepper/sweetcorn, Yellow show selected hybrid based on CR

all sweetcorn base intercropping. Ghosh *et al.*[36] justified that there is a positive advantage when competitive ratio was less than one and the crop can be grown in intercropping, but there was negative benefit when greater than one. Willey and Rao[37] showed that CR index measures competitive ability of the crops. It is also an advantageous index over relative crowding coefficient and aggressivity.

An exceptional occur in intercropping sweetcorn/chilli pepper 2:1 pattern, in which 3 hybrids showing CRj lower than CRc. The hybrids were MSR 17.6.7xSR 4, MSR 17.6.7xSR 17 and MSR 17.6.7xSR 43. An increase of chilli pepper yield higher compare to sweetcorn hybrids yield in this pattern was the important factor to explain why CRc is higher than CRj. This result suggesting that these hybrids could be developed as suitable hybrid in sweetcorn/chilli pepper intercropping system.

Tolerance of chilli pepper against sweetcorn hybrids cultivating in intercropping: The tolerance of chilli pepper in sweetcorn/chilli pepper intercropping was predicted by Stress Tolerance Index (STI). The STI used to identify high-yielding genotypes in both stress and non-stress conditions[14]. He categorized particular crop to be tolerance if STI value is high in which the mean performance of particular crop under stress condition would perform high or similar to one in optimal condition. In this research, STI of chilli pepper was estimated based on its fresh fruit weight, since its growth is under stress in intercropping with sweetcorn as indicated by its low CRc value.

The STI value of chilli pepper in intercropping with 38 sweetcorn hybrids under different pattern of sweetcorn is presented in Table 8. There is some hybrids show high STI including 13 hybrids and 4 hybrids for sweetcorn/chilli pepper 1:1 and 1:2 intercropping pattern and for sweetcorn/chilli pepper 2:1 intercropping pattern, respectively. Those hybrids were selected since it gives less stress to chilli pepper to yield higher than other non- selected hybrids.

Over all, stress due to cropping system reduced significantly the yield of chilli pepper and difference of STI suggests the genetic variability in sweetcorn hybrids for

Table 8: Stress Tolerance Index (STI) of 30 sweetcorn hybrids in intercropping sweetcorn/chilli pepper

Genotypes			PI 1		PI 2		PI 3	
SR 17	X	SR 4	**0.41**	**A**	0.20	C	**0.56**	**B**
SR 24	X	SR 4	**0.35**	**B**	0.22	C	0.43	D
SR 43	X	SR 4	**0.39**	**A**	0.19	D	0.49	C
MSR 17.2.3	X	SR 4	0.31	C	0.16	D	0.51	C
MSR 17.6.7	X	SR 4	**0.39**	**A**	**0.34**	**A**	**0.61**	**A**
MSR 25.2.6	X	SR 4	**0.37**	**B**	0.19	C	**0.53**	**B**
MSR 25.5.1	X	SR 4	**0.38**	**B**	0.22	C	**0.57**	**B**
SR 24	X	SR 17	0.31	C	0.24	C	0.52	C
SR 43	X	SR 17	**0.37**	**B**	0.14	D	0.50	C
MSR 17.2.3	X	SR 17	0.31	C	0.22	C	0.47	D
MSR 17.6.7	X	SR 17	**0.43**	**A**	**0.35**	**A**	0.50	C
MSR 25.2.6	X	SR 17	**0.40**	**A**	0.19	C	**0.54**	**B**
MSR 25.5.1	X	SR 17	**0.36**	**B**	0.23	C	**0.62**	**A**
SR 43	X	SR 24	0.31	C	**0.30**	**B**	**0.53**	**B**
MSR 17.2.3	X	SR 24	0.33	C	0.17	D	**0.57**	**B**
MSR 17.6.7	X	SR 24	0.26	D	0.20	C	0.49	C
MSR 25.2.6	X	SR 24	0.29	D	0.20	C	**0.54**	**B**
MSR 25.5.1	X	SR 24	0.32	C	0.22	C	**0.55**	**B**
MSR 17.2.3	X	SR 43	0.25	D	0.17	D	**0.57**	**B**
MSR 17.6.7	X	SR 43	**0.37**	**B**	**0.35**	**A**	**0.54**	**B**
MSR 25.2.6	X	SR 43	0.24	D	0.17	D	0.51	C
MSR 25.5.1	X	SR 43	0.33	C	0.20	C	0.51	C
MSR 17.6.7	X	MSR 17.2.3	0.29	D	0.19	C	0.46	D
MSR 25.2.6	X	MSR 17.2.3	0.29	D	0.23	C	0.43	D
MSR 25.5.1	X	MSR 17.2.3	0.31	C	0.13	D	0.50	C
MSR 25.2.6	X	MSR 17.6.7	0.20	D	0.17	D	0.46	D
MSR 25.5.1	X	MSR 17.6.7	**0.35**	**B**	0.22	C	0.46	D
MSR 25.5.1	X	MSR 25.2.6	**0.40**	**A**	0.17	D	**0.59**	**A**
Jambore			0.29	D	0.20	C	0.44	D
Sweetboy			0.33	C	0.20	C	0.52	C
Rata-rata STI			**0.33**	**C**	**0.21**	**C**	**0.52**	**C**

P1: Sweetcorn sole planting, P1: 1: Intercropping sweetcorn/chilli pepper 1:1, P2: 1: Intercropping sweetcorn/chilli pepper 2:1, P1: 2: Intercropping sweetcorn- chilli pepper 1:2, STI: Stress tolerance index, Yellow show selected hybrid based on STI

cultivating in intercropping with chilli pepper. With a careful selection of parents used in hybridization and with application of an appropriate selection method in segregating populations, it could be possible to obtain intercropping tolerance lines.

CONCLUSION

Parental line of MSR 17.2.3 is the best combiner for plant height, while SR 17 is the best combiner for maturity and ear weight per plant. The best combinations for high yield in both sole cropping and intercropping are MSR 12.6.7xSR 4 and MSR 25.5.1xSR 17. The MSR 17.6.7xSR 17 was the best hybrid for intercropping based on land equivalent ratio, competitive ratio and stress tolerance index analysis. Thus, MSR 17.6.7xSR 17 was suitable for sweetcorn/chilli pepper intercropping for the following aspects including high yield both in sole and intercropping system, moderately level of competition ratio against chilli pepper, low tolerance index to chilli pepper and higher productivity in 2:1 sweetcorn/chilli pepper intercropping system.

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