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Full Length Research Paper

Genetic variation and heritability of yield and related traits in promising rice genotypes (*Oryza sativa* L.)

S. A. Ogunbayo[1,3]*, M. Sié[1], D. K. Ojo[3], K. A. Sanni[1], M. G. Akinwale[2], B. Toulou[1], A. Shittu[2], E. O. Idehen[3], A. R. Popoola[3], I. O. Daniel[3] and G. B. Gregorio[4]

[1]Africa Rice Center (AfricaRice), 01 BP 2031, Cotonou, Benin Republic.
[2]Africa Rice Center, (AfricaRice), P. M. B. 5320, Ibadan, Oyo State, Nigeria.
[3]Department of Plant Breeding and Seed Technology, Federal University of Agriculture (FUNAAB), P. M. B. 2240, Abeokuta, Ogun State, Nigeria.
[4]International Rice Research Institute (IRRI), DAPO Box 7777, Metro Manila, Philippines.

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A study was conducted during 2008 to 2009 in 12 environments in Nigeria, Benin Republic and Togo to evaluate genetic variation and heritability of yield and related traits in 48 rice genotypes. The experiments were laid out in a randomized complete block design (RCBD) with three replications. Genotypes differed significantly at p > 0.001 for all the traits studied, which implies that the genotypes contain adequate genetic variability. Phenotypic coefficients of variation (PCV) were higher than genotypic coefficients of variation (GCV) in all the characters across the 12 environments. High heritability estimates were obtained for days to flowering (91.37), days to maturity (86.86), plant height at maturity, number of tiller per meter square, panicle shattering, panicle threshability, panicle per meter and panicle length (72.21) suggesting that the traits are primarily under genetic control. High estimates of heritability, GCV and genetic advance (GA) observed for grain yield is an indication that selection for grain yield could be achieved through phenotypic performance. Furthermore, high estimates of heritability, GA and GCV recorded in these characters could be explained by additive gene action. Low estimates of heritability, GCV and GA recorded for grain yield and number of grains per panicle could be due to non-additive gene effect suggesting that these traits were less responsive to specific environment influences. Grain yield recorded highly significant positive correlation with panicle length (0.28), leaf width (0.40), grain length (0.30), number of panicles per meter square (0.19) and1000-grain weight (0.17). It correlated negatively with basal leaf sheath coloration (-0.33) and grain width (-0.20) in the 12 environments. The current study indicated that more number of tillers, panicles per meter square, long panicles, high number of primary and secondary branch panicles and large 1000-grain weight are important yield related traits and could be used for selection in rice breeding programs.

Key words: Correlation coefficients, heritability, phenotypic coefficients, rice, variability, yield components.

INTRODUCTION

Rice is the most rapidly growing food commodity in sub-Saharan Africa (SSA), mainly driven by urbanization. It has become a commodity of strategic significance and the fastest-growing food source in Africa, such that its availability and price are now a major determinant of the welfare of the poorest segments of consumers who are

the least food-secure consumers in Africa. It is no longer a luxury food but has become the cereal that constitutes a major source of calories for the urban and rural poor (Ogunbayo et al., 2005; Seck et al., 2013). Rice is now grown and consumed in more than 40 African countries, where about 20 million farmers are engaged in its production and about 100 million people depend on rice directly for their livelihood (Nwanze et al., 2006). The world population is expected to reach 8 billion by 2030 and rice production must be increased by 50% in order to meet the growing demand (Khush and Brar, 2002). The demand for rice in SSA is expected to grow substantially as the population is currently growing at the rate of 3 to 4% per annum and rice consumption is growing faster than that of any major food. However, self-sufficiency in African rice production is declining as demand increases, driving the urgent need to increase and improve the continent's production of rice to satisfy the high demand (Sanni et al., 2012). To attain rice self-sufficiency and meet the future demand resulting from population growth, development of high yielding genotypes with desirable agronomic traits for diverse ecosystem is therefore, a necessity (Ogunbayo et al., 2007; Akinwale et al., 2011; Mulugeta et al., 2012).

The development of high yielding cultivars with wide adaptability is the ultimate aim of plant breeders. Therefore, by exploiting the good adaptation and stability of yield and its components in rice genotypes, it would be possible to develop/identify high yielding and well adapted varieties (Ogunbayo, 2011). Thus, effective yield component breeding to increase grain yield could be achieved, if the components traits are highly heritable and positively correlated with grain yield (Sabesan et al., 2009; Ullah et al., 2011). The knowledge of genetic variability present in a given crop species for the character under improvement is of paramount importance for the success of any plant breeding program, heritability and genetic advance (GA) are important selection parameters.

Genetic variability is important for breeding and in selecting desirable traits. Thus, character association of component traits with yield and among themselves is very important. The relationship between rice yield and yield component traits has been studied widely at a phenotypic level. Idris et al. (2012) observed positive phenotypic and genotypic correlation coefficient between grain yield and number of filled grains per panicle, harvest index, panicle length and number of grains per panicle. Sadeghi (2011) observed positive significant association of grain yield with grains per panicle, days to maturity, number of productive tillers and days to flowering. Ullah et al. (2011) detected that grain yield was positively and significantly associated with panicle length and grains per panicle. Hairmansis et al. (2010) also recorded a positive and significant association of grain yield with filled grains per panicle, spikelets per panicle and spikelet fertility.

Heritability estimates along with GA are normally more helpful in predicting the gain under selection than heritability estimates alone. Therefore, the estimation of heritability for any trait requires the partitioning of the observed variation between genetic effects and environmental effects (Cockerham, 1963). However, when the phenotypic variability is large, traits with high heritability values are subject to large genetic gains per generation when selection is applied (Dudley and Moll, 1969; Hesse, 1975; Hansche, 1983; Falconer, 1989; Nyquist, 1991). The broad sense heritability is the relative magnitude of genotypic variance for the traits and it gives an idea of the total variation accounted to genotypic effect (Allard, 1960).

Karthikeyan et al. (2010) recorded broad sense heritability estimates of 99.8% for days to flowering, 99.2% for days to maturity, 87.3% for plant height, 79.8% for panicle length, 93.4% for a number of branches per panicle, 88.8% for number of fertile florets per plant, 97.6% for 1000 grain weight and 73.2% for grain yield plant. Padmaja et al. (2008) also reported 98.52% for days to flowering, 99.05% for plant height, 78.72% for total tillers per plant and 76.82% for productive tillers per plant, 81.54% for panicle length and 99.38% for grains per panicle, 99.46% for spikelet fertility, 87.21% for 100 grain weight and 94.21% for single plant yield.

The objective of this study was to assess genetic variability and heritability of yield and yield components in 48 rice genotypes.

MATERIALS AND METHODS

Forty-eight (48) rice varieties that included 37 interspecific (*Oryza glaberrima* × *Oryza sativa indica*) and 11 intraspecific (*O. sativa indica* × *O. sativa indica*) were evaluated in 2008 and 2009 wet seasons at the International Institute of Tropical Agriculture (IITA) Ibadan (Nigeria), Africa Rice Center (AfricaRice) Ouédémé (Benin Republic) and Farmers field in Kpalime (Togo). All the varieties used for the experiment were collected from the lowland breeding unit and Genebank of Africa Rice Center, Cotonou, Benin. Field evaluation was carried out under irrigated lowland, valley bottom and valley fringe conditions. Randomized complete block design (RCBD) with three replications was used in all locations and years. Each plot size was 1 × 5 m with 20 cm within and between rows. Five rows per plot and inter-plot spacing of 40 cm was used. Seeds were sown directly for valley bottom and valley fringe environments at 2 seeds per hill and latter thin to one plant. Nursery beds were prepared for the irrigated plots and seedlings were transplanted at 21 days old. NPK (15-15-15) fertilizer was applied as basal application at the rate of 200 kg/ha before transplanting and top dressed with urea at the rate of 65 kg/ha at the tillering stage

*Corresponding author. E-mail: a.ogunbayo@cgiar.org

Table 1. List of characters studied in the experiment.

Character	Abbreviation
Plant vigor	Pltvigor
Number of tiller at 60 days	NmTiller
Flowering date	Flwdays
Maturity date	Matdays
Plant height (cm)	PltHght
Panicle exertsion	PanExt
Panicle shattering	PSht
Panicle threshability	Pthres
Yield (gms)	Yld
Hairnes	Hairnes
Panicle number/m^2	Pan_m
Awning	Awning
Panicle length (cm)	Panlght
Primary branch panicle	Prybrpan
Secondary branch panicle	Secbrpan
Leaf length (cm)	Lflgth
Leaf width (cm)	Lfwdth
Flag leaf angle	FlaglAng
Base tiller coloration	Bastlcol
Grain length (mm)	Grlght
Grain width (mm)	Grwidth
1000 grain weight (gms)	1000grwt

followed by 35 kg/ha at booting stage. The plots were hand-weeded regularly to minimize weed infestation.

Data collection and analysis

Morphological data were collected for 22 quantitative and qualitative characters at appropriate growth stage of rice plant following the Standard Evaluation System (IRRI, 2002). The characters that were evaluated included days to 50% flowering, days to 85% maturity, plant height, number of tiller at 60 days, number of panicles per m^2, grain yield, panicle length, panicle exsertion, plant vigor, panicle shattering, panicle threshability, hairness, awning, primary panicles branching, secondary panicles branching, leaf length, leaf width, flag leaf angle, basal leaf sheath colour, grain length, grain width and 1000-grain weight. The characters that were evaluated are shown in Table 1. The data collected on 22 agro-botanical traits from the rice accessions were subjected to statistical analysis using SAS/PC version 9 packages (SAS Institute, 2000). Analysis of variance (ANOVA) was carried out on the data to assess the genotypic effects and their interaction using a general linear model (GLM) procedure for RCBD in SAS (9.2 version). Estimates of variance components were generated. Broad-sense heritability (h2) was calculated as the ratio of the genotypic variance to the phenotypic variance using the formula according to Allard (1960):

$h^2 = O'^2g / O'^2ph \times 100$

Where h^2 = broad sense heritability (%), O'^2g = genotypic variance and O'^2ph = phenotypic variance.

GA was calculated at 20% selection intensity (I = 1.4). Phenotypic coefficients of correlation were computed using Pearson's linear correlation outlined by Steel and Torrie (1984).

RESULTS

Table 2 presents combined ANOVA for flowering days, maturity days, plant height, panicle/m^2 and yield of 48 rice genotypes at 12 environments. Significant replicate effects were observed for flowering days, maturity days, plant height, panicle/m^2 and yield. Also, the result indicates that the rice genotypes varied significantly with respect to all traits. The location, genotype × locations were highly significant to all traits except panicle/m^2. The 2 years differed significantly with respect to all traits meaning that climatic changes were observed during the study. Significant genotype × year effects were observed for flowering days and maturity days but non-significant G × E effects were observed for plant height, panicle/m^2 and yield meaning that the last three traits remained similar over the 2 years. Location × year interaction reported highly significant effects for all the five traits meaning that the location of experiments differed in the 2 years of the study, suggesting that rice genotypes performed differently in every location in each year. Genotype × location × year were significant with respect to flowering days and yield and non-significant effects were observed for maturity days, plant height and panicle/m^2.

Table 3 presents means, estimates of genotypic and phenotypic variance, genotypic coefficients of variation (GCV) and phenotypic coefficients of variation (PCV), broad-sense heritability and GA expressed as percentage of mean over twelve environments. Expectedly, phenotypic variances were generally higher than the genotypic variances in all the characters studied. The highest phenotypic and genotypic variances in all the characters considered were recorded in yield (1667418.63 and 743746.19), respectively. Equally, high phenotypic and genotypic variances were observed in number of panicles per meter square (89.00 and 48.72) and plant height at maturity (64.00 and 58.02), respectively. The PCV generally ranged between 2.87% for maturity date and 563.18% for awning, respectively. Similarly, the GCV ranged between 2.68% for maturity date and 563.18% for awning. Generally, heritability in the broad-sense estimate varied from 46.98% for panicle exertion and 100.00% for awning, respectively. Similarly, GA had a general range between 5.14% for maturity date and 160.16% for awning. A joint consideration of GCV, broad-sense heritability estimates and GA revealed that panicle shattering (16.28, 86.50, and 31.19%), panicle threshability (23.67, 93.60, and 47.17%), hairiness (29.49, 94.39, and 59.03%), flag leaf angle (35.89, 89.47, and 69.93%), basal leaf sheath colour (63.08, 95.75, and 127.16%) combined high GCV, heritability and high GA, whereas number of tillers per meter square (5.68, 66.22, and 9.52%), days to flowering (4.19, 91.37, and 8.24%), yield (22.32, 44.6, and 30.7%) combined high heritability with moderate, GCV and GA.

Table 4 presents phenotypic correlation coefficient between 22 characters of rice in 12 environments (6

Table 2. Mean squares of the combined analysis of variance for yield and related characters of forty-eight rice genotypes at 12 environments (6-locations by 2-seasons).

Source	DF	Flowering days	Maturity days	Plant height	Panicle/m^2	Yield (kg)
Rep	2	405.57**	320.90*	935.73*	17802.79**	3172332.00*
Genotype	47	573.99**	445.64**	2510.16**	3224.97*	4241473.00**
Location	5	3415.67**	3293.76**	16468.86**	58159.07**	478999838.00**
Genotype × location	235	39.00**	59.01**	431.84**	1640.01^{ns}	2045861.00**
Year	1	598.55**	987.06**	11891.26**	2518782.18**	214102592.00**
Genotype × year	47	55.59**	74.22*	60.48^{ns}	1076.35^{ns}	1323782.00^{ns}
Location × year	5	11053.14**	4314.64**	6147.59**	662751.43**	337035964.00**
Genotype × location × year	235	56.47**	48.14^{ns}	60.66^{ns}	1267.41^{ns}	1876652.00*
Error	1150	23.14	39.26	107.85	1895.73	1411702.00

, * Significant at 5 and 1% probability levels, respectively.

Table 3. General mean, estimate of phenotypic and genotypic variance, phenotypic and genotypic coefficient of variability (PCV and GCV), broad sense heritability and genetic advance (GA) expressed for 48 rice genotypes

Character	Grand mean	Phenotypic variance	Genotypic variance	Environmental variance	PCV	GCV	Broad-sense Heritability	GA (%)
Plant Vigor	2.98	0.17	0.12	0.02	13.94	11.86	72.41	20.79
Number of Tiller	12.16	0.72	0.48	0.14	6.98	5.68	66.22	9.52
Flowering days	89.28	15.28	13.96	0.60	4.38	4.19	91.37	8.24
Maturity days	119.07	11.72	10.18	1.10	2.87	2.68	86.86	5.14
Plant height	100.57	64.00	58.02	2.91	7.95	7.57	90.65	14.85
Panicle exertion	5.92	0.25	0.12	0.03	8.39	5.75	46.98	8.12
Panicle shattering	3.83	0.45	0.39	0.01	17.51	16.28	86.50	31.19
Panicle threshability	5.42	1.76	1.65	0.00	24.46	23.67	93.60	47.17
Yield	3864.26	1667418.63	743746.19	923672.45	33.42	22.32	44.60	30.70
Hairness	2.10	0.41	0.38	0.00	30.36	29.49	94.39	59.03
Panicle/meter square	198.51	89.00	48.72	44.12	4.75	3.52	54.74	5.36
Awning	0.13	0.54	0.54	0.00	563.18	563.18	100.00	160.16
Panicle length	25.93	2.41	1.74	0.70	5.98	5.08	72.21	8.90
Primary branch panicle	9.74	0.53	0.41	0.03	7.49	6.57	76.91	11.86
Secondary branch panicle	19.80	5.86	4.13	0.63	12.23	10.26	70.40	17.73
Leaf length	29.05	3.23	2.66	0.60	6.19	5.61	82.23	10.48
Leaf width	1.05	0.00	0.00	0.00	5.15	4.33	70.48	7.48
Flag leaf angle	1.64	0.39	0.35	0.01	37.94	35.89	89.47	69.93
Base tiller coloration	1.42	0.84	0.80	0.00	64.47	63.08	95.75	127.16
Grain length	8.84	0.10	0.10	0.00	3.65	3.49	91.39	6.87
Grain width	2.34	0.01	0.01	0.00	4.57	4.38	91.97	8.65
l000grwt	23.56	0.73	0.64	0.05	3.62	3.39	87.74	6.54

locations by 2 seasons). Plant vigor was negatively and significantly associated with plant height (-0.48), primary branch panicle (-0.29), secondary branch panicle (-0.26), leaf length (-0.37) and positively significantly correlated with panicle per meter square (0.17). Number of tillers per meter square was negatively and significantly correlated with plant height (-0.25) and primary branch panicle (-0.18%). Days to flowering revealed highly significant positive correlation with maturity date (0.93), plant height (0.60), primary branch panicle (0.55), secondary branch panicle (0.38), leaf length (0.58), flag leaf angle (0.37) and significant to grain width, however, days to flowering also had highly significant negative correlation with panicle exertion (-0.28) and significant negative correlation with hairiness (-0.16).

Days to maturity had highly significant positive

Table 4. Phenotypic correlation coefficient among 22 characters of 48 rice genotypes.

Character	No Till	Flw days	Mat days	Plt Hght	Pan Ext	PSht	Pthres	Yld	Hairness	Pan/m	Awn	Pan lght	Pry brpan	Sec brpan	Lf lght	Lf wdth	Flagl Ang	Bastl col	Gr lght	Gr width	l000 gwt
Pltvigor	0.07	0.03	-0.04	-0.48**	-0.06	0.04	-0.10	0.12	0.14	0.17*	-0.13	-0.06	-0.29**	-0.26**	-0.37**	0.07	-0.15	-0.07	0.11	0.08	-0.01
NmTiller		0.10	0.09	-0.25**	-0.07	-0.05	-0.06	-0.03	0.06	0.01	-0.04	-0.07	-0.18*	0.03	-0.02	0.03	-0.12	-0.04	-0.11	-0.14	0.05
Flwdays			0.93**	0.60**	-0.28**	-0.03	0.15	-0.01	-0.16*	-0.10	0.11	0.17	0.55**	0.38**	0.58**	0.04	0.37**	0.09	-0.12	0.16*	-0.12
Matdays				0.61**	-0.21**	-0.04	0.14	0.04	-0.13	-0.14	0.15	0.22**	0.59**	0.46**	0.67**	0	0.34**	0.09	-0.12	0.03	-0.07
PltHght					-0.08	-0.08	0.18*	-0.17*	-0.27**	-0.18*	-0.01	0.13	0.64**	0.39**	0.58**	-0.16*	0.39**	0.11	-0.24**	0.22**	-0.14
PanExt						-0.11	-0.11	0.18*	-0.05	-0.09	-0.04	-0.16*	0.14	0.01	-0.20*	0.27**	-0.19*	-0.30**	0.04	0.15	-0.14
PSht							0.20*	0.34**	-0.27**	0.06	-0.18*	0.16*	-0.04	0.03	-0.11	0.02	-0.15	-0.15	-0.01	0	-0.21
Pthres								-0.03	-0.18**	-0.15*	0.02	0.08	0.15	0.14	0.21**	-0.18*	0.03	0.07	-0.04	-0.04	-0.03
Yld									-0.07	0.19*	0.00	0.28**	0.16*	0.16*	0.02	0.40**	-0.05	-0.33**	0.30**	-0.20*	0.17*
Hairnes										0.08	0.46**	-0.28**	-0.16*	-0.20*	-0.29**	0.02	0.20*	0.23**	0.01	-0.11	0.00
Pan_m											0.17*	-0.03	-0.25**	-0.03	-0.10	0.09	-0.01	0.03	0.27**	0.01	-0.03
Awning												0.02	0.13	0.16*	0.11	0.07	0.42**	0.24**	-0.08	-0.18*	0.00
Panlght													0.24**	0.36**	0.39**	0.12	-0.11	-0.15	0.15	-0.22**	0.06
Prybrpan														0.73**	0.53**	-0.1	0.24**	-0.24**	-0.05	0.23**	-0.24*
Secbrpan															0.59**	-0.22**	-0.02	-0.25**	0.05	0.09	-0.13
Lflgth																-0.14	0.05	0.06	0.1	-0.17*	0.03
Lfwdth																	0.12	0	-0.09	0.15	0.16*
Lfwdth																		0.34**	-0.50**	0.22**	-0.09
Bastlcol																			-0.19*	-0.13	0
Grlght																				-0.22**	0.07
Grwidth																					-0.24**

correlation with plant height (0.61), panicle length (0.22), primary branch panicle (0.59), secondary branch panicle (0.46), leaf length (0.67), flag leaf angle (0.34) and significant negative correlation with panicle exertion (-0.21). Plant height had highly significant positive correlation with primary branch panicle (0.64), secondary branch panicle (0.39), leaf length (0.58), flag leaf angle (0.39) and grain width (0.22). Similarly, plant height significantly and positively correlated with panicle threshability. However, plant height had significant negative correlation with yield (-0.17), leaf width (-0.16) and highly significant negative correlation with grain length (-0.24).

Panicle exertion had highly significant positive correlation with leaf width (0.27) and significant correlation with yield. Meanwhile, panicle exertion showed a significant negative correlation with panicle length (-0.16), leaf length (-0.20), flag leaf angle (-0.19) and highly significant with basal leaf sheath coloration (-0.30). Panicle shattering had highly significant positive correlation with yield (0.34) and significant positive correlation with panicle threshability (0.20), and panicle length (0.16). However, highly significant negative correlation was observed with hairiness (-0.27) and significant correlation with (-0.18).

Panicle threshability had highly significant negative correlation with hairiness (-0.18), and significant correlation with panicle per meter square (-0.15), and leaf width (-0.18). However, highly significant positive correlation was observed with leaf length (0.21). Yield had highly significant positive correlation with panicle length (0.28), leaf width (0.40), grain length (0.30), and significant to panicle per meter square (0.19), primary branch panicle (0.16), secondary branch panicle (0.16), 1000 grain weight (0.17) and also had highly significant negative correlation with basal leaf

sheath coloration (-0.33) and significant to grain width (-0.20). Hairiness had highly significant positive correlation with awning (0.46), basal sheath coloration (0.23) and significant positive correlation with flag leaf angle (0.20). Similarly, highly significant negative correlation was observed with panicle length (-0.28), leaf length (-0.29), and significant with primary branch panicle (-0.16) and secondary branch panicle (-0.20).

Panicle per meter square was highly and positively significant correlated with grain length (0.27) and significant with awning (0.17). However, highly significant correlation was observed with primary branch panicle (-0.25). Awning had highly significant positive correlation with flag leaf angle (0.42), basal sheath coloration (0.24) and significant with secondary branch panicle (0.16) and negative with grain width (-0.18).

Panicle length was highly significant positively correlated with primary branch panicle (0.24), secondary branch panicle (0.36) and leaf length (0.39) and highly significant and negatively correlated with grain width (-0.22). Primary branch panicle had highly significant positive correlation with secondary branch panicle (0.73), leaf length (0.53), flag leaf angle (0.24), grain width (0.23) and highly significant negative correlation with basal sheath coloration (-0.24) and significant to 1000 grain weight (-0.24).

Secondary branch panicle was significantly and negatively correlated with leaf width (-0.22), basal sheath coloration (-0.25) and positively significantly correlated to leaf length (0.59). Leaf length was significant negatively correlated with grain width (-0.17). Leaf width also had significant negative correlation with 1000 grain weight (0.16). Leaf width had highly significant correlation with basal sheath coloration (0.34), grain width (0.22) and similarly had highly significant and negative correlation with grain length (-0.50). Basal sheath coloration had significant and negatively correlated with grain length (-0.19).

Grain length had a highly significant negative correlation with grain width (-0.22) and grain width had highly significant correlation with 1000 grain weight (-0.24)

DISCUSSION

The present study results indicated that there is adequate genetic variability present in the materials studied. The PCV was higher than the GCV in all the characters across the 12 environments. The difference between PCV and GCV is probably accounted for by the environmental effects. There was high heritability estimates for days to flowering, days to maturity, plant height at maturity, number of tiller per meter square, panicle shattering, panicle threshability, panicle per meter and panicle length suggesting that environmental factors did not affect greatly the phenotypic performance of these traits. Thus, high estimates of heritability GCV and GA may be good predictors of seed yield in rice. Hence, selection based on the phenotypic performance of these characters will be reliable and effective.

Murtadha et al. (2004) suggested that traits with high heritability estimates, GA and GCV could be good predictors of seed yield in crops. Ibrahim and Hussein (2006) had a similar view in their report on *Hibiscus sabdarifa*. Furthermore, the moderate to high estimates of heritability, GA and GCV recorded in days to flowering, days to maturity, plant height at maturity, number of tiller per meter square, panicle shattering, panicle threshability, panicle per meter and panicle length could be explained by additive gene action and hence their improvement can be done through mass selection (Ibrahim and Hussein, 2006). However, non-additive gene effect could be the explanation for the low heritability, GCV and GA recorded for mature grain and number of seeds per panicle (Yadev, 1996; Koorse, 1987; Subramayan et al., 1995), suggesting that these traits could be improved by developing hybrid varieties, through recurrent selection method because they are less responsive to improvement by selection in specific environment, hence the need to breed for specific environment.

For inter-character association estimates to be repeatable, such character must be both significantly genotypic and phenotypically correlated for any selection based on this is reliable. The positive significant phenotypic and genotypic correlations between plant height at maturity, panicle length, primary branch panicle, secondary branch panicle, panicle per meter square in all environments is strong indication that these traits are major factors in relation to seed yield. This suggests that selection directed towards these characters will be effective in ensuring seed yield in rice. However, under phenotypic correlation, yield had highly significant positive correlation with panicle length (0.28), leaf width (0.40), grain length (0.30), and significant to panicle per meter square (0.19), primary branch panicle (0.16), secondary branch panicle (0.16), 1000 grain weight (0.17) and also had highly significant negative correlation with basal leaf sheath coloration (-0.33) and significant to grain width (-0.20) in 12 environments. Similarly, under genotypic correlation, yield was highly and positively significant correlated with panicle length (0.79), primary branch panicle (0.24), secondary branch panicle (0.26), grain length (0.37) and 1000 grain weight (0.24). These results suggest that selection to improve rice yield directed by the phenotype of these traits may be effective and negative correlation between yield and grain width may be due to the inability of the plant to feed and fill longer grain compared to shorter grains, hence making plants with longer panicle to have fewer numbers of grains and consequently having lower seed yield.

Therefore, from a present study, it can be concluded that for increasing rice grain yield, a genotype should possess more number of tillers, panicle per meter square,

panicle length, high primary and secondary branch panicle and 1000 grain weight. The results suggest that these characters are important yield contributing traits and selection on these traits would be most effective.

Conflict of Interest

The author(s) have not declared any conflict of interest.

REFERENCES

Akinwale MG, Gregorio G, Nwilene F, Akinyele BO, Ogunbayo SA, Odiyi AC (2011). Heritability and correlation coefficient analysis for yield and its components in rice (Oryza sativa L.). Afr. J. Plant Sci. 5: 207-212.

Allard RW (1960). Principles of Plant Breeding. 1st Edn., John Wiley and Sons, Inc. New York. P. 485.

Cockerham CC (1963). Estimation of genetic variances, pp. 53-93. In: W.D. Hanson and H. F. Robinson (eds). Statistical genetics and plant breeding. Natl. Acad. Sci. - Nat. Res, Council, Washington, D. C., Publ. 982

Dudley JW, Moll RH (1969). Interpretation and use of estimates of heritability and genetic variances in plant breeding. Crop Sci. 9:257-261.
http://dx.doi.org/10.2135/cropsci1969.0011183X000900030001x

Falconer DS (1989). Introduction to quantitative genetics. 3rd ed. Longman Sci. and Techn. London. P. 11.

Hairmansis A, Kustianto B, Supartopo S (2010). Correlation analysis of agronomic characters and grain yield of rice for tidal swamp areas. Indonesian J. Agric. Sci. 11:11-15.

Hansche PE (1983). Response to selection, In: JN Moore, J. Janick (eds.). Methods in fruit breeding. Purdue Univ. Press, West Lafayette, Ind. pp. 154-171.

Hesse CO (1975). Peaches, In: J. Janick, JN. Moore (eds.). Methods in fruit breeding. Purdue Univ. Press, West Lafayette, Ind. pp. 285-335.

Ibrahim MM, Hussein RM (2006). Variability, heritability and genetic advance in some genotypes of Roselle (Hibiscus sabdariffa L.) World J. Agric. Sci. 2(3):340-345.

Idris AE, Justin FJ, Dagash YMI, Abuali AI (2012). Genetic Variability and Inter Relationship between Yield and Yield Components in some Rice Genotypes. Am. J. Exp. Agric. 2(2):233-239.
http://dx.doi.org/10.9734/AJEA/2012/961

IRRI (2002). Standard evaluation system for rice. International Rice Research Institute (IRRI), Manila, November 2002. http://www.knowledgebank.irri.org/ses/SES.htm

Karthikeyan P, Anbuselvam Y, Elangaimannan R, Venkatesan M (2010). Variability and Heritability Studies in Rice (Oryza sativa L.) under coastal salinity. J. Plant Breed. 1(2):196-198.

Khush GS, Brar DS (2002). Biotechnology for rice breeding: Progress and impact. Proceedings of the 20th Session of the International Rice Commission, July 23-26, 2002, Bangkok, Thailand.

Koorse KV (1987). Genetic variability studies in Roselle (Hibiscus sabdariffa L.). J. Agric. Sci. 21:90-91.

Mulugeta S, Sentayehu A, Kassahun B (2012). Genetic variability, heritability, correlation coefficient and path analysis for yield and yield related traits in upland rice (Oryza sativa L.). Journal of Plant Sciences 7 (1): 13-22.
http://dx.doi.org/10.3923/jps.2012.13.22

Murtadha S, Ariyo OJ, Kehinde OB (2004). Character association of seed yield and its components in okra [Abelmoschus esculentus (L.) Moench]. Ogun J. Agric. Sci. 3(1):222-233.

Nwanze KF, Mohapatra S, Kormawa P, Keya S, Bruce-Oliver S (2006). Rice development in sub-Saharan Africa. J. Sci. Food Agric. 86:675-677.
http://dx.doi.org/10.1002/jsfa.2415

Nyquist WE (1991). Estimation of heritability and prediction of selection response in plant populations. Crit. Rev. Plant Sci. 10:235-322.
http://dx.doi.org/10.1080/07352689109382313

Ogunbayo SA (2011). Genetic variation, correlation studies and multilocational performance of lowland NERICA Rice (Oryza species L). PhD Thesis, Federal University of Agriculture, Abeokuta, Nigeria.

Ogunbayo SA, Ojo DK, Guei RG, Oyelakin O, Sanni KA (2005). Phylogenetic diversity and relationship among forty rice accessions using Morphological and RAPDs techniques. Afr. J. Biotechnol. 4:1234-1244.

Ogunbayo SA, Ojo DK, Popoola AR, Ariyo OJ, Sie M, Sanni KA, Nwilene FE, Somado EA, Guei RG, Tia DD, Oyelakin OO, Shittu A (2007). Genetic Comparisons of Landrace Rice Accessions by Morphological and RAPDs Techniques. Asian J. Plant Sci. 6(4):653-666.
http://dx.doi.org/10.3923/ajps.2007.653.666

Padmaja D, Radhika K, Subba Rao LV, Padma V (2008). Studies on Variability, Heritability and Genetic Advance for Quantitative Characters in Rice (Oryza sativa L.). J. Plant Genet. Resour. 21(3).

Sabesan T, Suresh R, Saravanan K (2009). Genetic variability and correlation for yield and grain quality characters of rice grown in costal saline lowland of Tamiluadu. Elect. J. Plant Breed. 1:56-59.

Sadeghi SM (2011). Heritability, phenotypic correlation and path coefficient studies for some agronomic characters in landrace rice varieties. World Appl. Sci. J. 13:1229-1233.

Sanni KA, Fawole I, A.Ogunbayo S, Tia DD, Somado EA, Futakuchi K, Sie M, Nwilene FE, Guei RG (2012). Multivariate analysis of diversity of landrace rice germplasm. Crop Sci. 52:494-504.
http://dx.doi.org/10.2135/cropsci2010.12.0739

SAS Institute (2000). SAS Linear Model: A Guide to ANOVA and GLM Procedures. SAS Inst. Inc., Cary, NC, USA

Seck PA, Toure AA, Coulibaly JY, Diagne A, Wopereis MCS (2013). Africa's Rice Economy before and after 2008 rice crisis pp. 24-34. In: Wopereis MCS, Johnson DE, Ahmadi N, Tollens E, Jalloh A (Eds), Realizing Africa's Rice Promise. CABI International (UK) and AfricaRice (Benin) 480 pp.
http://dx.doi.org/10.1079/9781845938123.0024

Steel RG, Torrie JH (1984). Principles and procedure of statistics, pp. 137-167.

Subramayan D, Kumar PVR, Krishnamurthy B, Islam S (1995). Heritability and Correlation studies in Kenaf (Hibiscus cannabinus L.) Indian J. Genet. Plant Breed. 55:279-282.

Ullah MZ, Bashar MK, Bhuiyan MSR, Khalequzzaman M, Hasan MJ (2011). Interrelationship and cause-effect analysis among morpho-physiological traits in biroin rice of Bangladeshi. Int. J. Plant Breed. Genet. 5:246-254.
http://dx.doi.org/10.3923/ijpbg.2011.246.254

Yadev DS (1996). Correlation and path coefficient analysis of some important characters in okra (Abelmoschus esculentus [L.] Moench). J. Hill Res. 9(1):157-158.

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Review

Management of major diseases and insect pests of onion and garlic: A comprehensive review

R. K. Mishra[1]*, R. K. Jaiswal[2], D. Kumar[3], P. R. Saabale[4] and A. Singh[5]

[1]Division of Biotechnology and Bioresources, The Energy and Resources Institute (TERI), New Delhi-110003, India.
[2]Krishi Vigyan Kendra Panna, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Madhya Pradesh-488 001, India.
[3]Department of Genetics and Plant Breeding, Narendra Dev University of Agriculture and Technology, Kumarganj, Faizabad, Uttar Pradesh, India.
[4]Indian Institute of Pulses Research (IIPR), Kanpur-204028, India
[5]Ram Manohar Lohia Awadh University, Faizabad, Uttar Pradesh, India.

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Onion (*Allium cepa* L.) and garlic (*Allium sativum* L.) are the most important commercial crops grown all over the world and consumed in various forms. In India, onion and garlic have been under cultivation for the last 5000 years. It is generally used as vegetables, spices or as medicines. India ranks second to China in area and production in both onion and garlic, but ranks 102nd for onion and 74th for garlic in terms of productivity. These crops are generally grown throughout the country especially in the states of Maharashtra, Uttar Pradesh, Orissa, Gujarat, Madhya Pradesh, Haryana, Punjab, Rajasthan, Uttaranchal, Jammu and Kashmir, Bihar, Andhra Pradesh and Karnataka. The onion and garlic crop is attacked by many diseases and insect pests at different crop growth stages which causes considerable losses in yield. Apart from reduction in crop yield, the disease and insect pests also poses harmful effects during harvesting, post harvesting, processing and marketing stages, which lower the quality and export potential of the crops that significantly causes the economic loss. The diseases and insect pests alter the cropping pattern and also affect the local and export markets. The consistent use of chemicals to control the plant diseases and insect pests not only poses a serious threat to the environment and mankind but also slowly build up resistance in the pathogens and insect pests. Most of the new generation pesticides are systemic in their mode of action which may leads to certain level of toxicity in the plant system and thus resulting health hazards. Further, it disturbs the microbial diversity which is an important part of the ecosystem. All these factors have led to new dimension in research for biological control and integrated approach for the management of plant diseases and insect pests. Important diseases and insect pests affecting the onion and garlic crops along with their management are briefly summarized in the present manuscript.

Key words: Onion (*Allium cepa* L.), garlic (*Allium sativum* L.), *Trichoderma viride*, bulbs.

INTRODUCTION

Onion (*Allium cepa* L.) and garlic (*Allium sativum* L.) is one of the most important commercial vegetable crops grown in India and being used as vegetables, spices or as medicines. The genus *Allium* also contains a number

*Corresponding author. E-mail: rajpathologist@yahoo.com.

Table 1. Major diseases and insect pests.

Name of disease	**Damping-off**
Causative agent	*Pythium* sp *Phytophthora* sp *Rhizoctonia solani* (Kuhn) *Fusarium* sp
Area and distribution	Damping off is an important disease of onion during nursery stage which causes about 60 to 75% damage to the crop. The disease is more prevalent during *kharif* (rainy) season and causes delayed seedling emergence in addition to root and basal rots. High soil moisture and moderate temperature along with high humidity especially in the rainy season leads to the development of the disease.
Symptomatology	Two types of symptoms are observed which are as follows: Pre-emergence damping-off: The pre-emergence damping off results in seed and seedling rot before these emerge out of the soil. Post-emergence damping-off: The pathogen attacks the collar region of seedlings on the surface of soil. The collar portion rots and ultimately the seedlings collapse and die.
Management strategies	i. Healthy seeds should be selected for sowing. ii. Continuous raising of nursery in the same plot should be avoided. iii. Application of safer fungicides in soil at the time of nursery raising can substantially reduce the crop damage. iv. Soil solarization by spreading 250 gauge polythene sheet over the bed for 30 days before sowing and application of bio-control agent. v. The seed should be treated with Thiram or captan at 2 g/kg of seed before sowing. vi. The top soil of nursery should be treated with Thiram or captan at 5 g/m^2 area of the soil and nursery should be drenched with the same chemical at 2 g/litre of water at fortnight interval. vii. *Trichoderma viride* in soil *at* 4 to 5 kg/ha is also found effective to control damping-off to considerable extent
Name of disease	**Purple blotch**
Causative agent	*Alternaria porri* (Ellis) Cif.
Area and distribution	It is an important disease of onion and garlic prevalent in all the onion and garlic growing areas in the world. Hot and humid climate with temperature ranging from 21 to 30°C and relative humidity (80 to 90%) favors the development of the disease. It is more common in *kharif* season. The intensity of disease varies from season to season, variety to variety and region to region.
Symptomatology	The fungal spores germinate on onion leaves and produce a small, water-soaked spot that turns brown. The elliptical lesion enlarges, becomes zonate (target spot) and purplish. The margin may be reddish to purple and surrounded by a yellow zone. During moist weather, the surface of the lesion may be covered by brown to black masses of fungal spores. Lesions may merge or become so numerous that they kill the leaf. Leaves become yellow then brown and wilt 2 to 4 weeks after initial infection. Lesions may form on seed stalks and floral parts of seed onions and affect seed development. Diseased tissue turns brown to black and dries out in the field or more commonly in storage. Purple blotch first appears as small, whitish sunken lesions. Almost immediately, the spots turn brown, enlarge, and become zoned, somewhat sunken, and more or less purplish. The lesions occur on the leaves, flower stalks, and floral parts of seed onions. The lesion borders are reddish and surrounded by a yellow “halo.” If conditions are favorable for disease development, the lesions quickly girdle the leaves and seed stems. Affected leaves and stems may turn yellow, die back, collapse, and die within several weeks after the first lesions appear. In moist weather, diseased tissues are covered with a dense, dark purplish black mold composed of large numbers of microscopic, dark multi-celled spores (conidia). The conidia are carried to other onion leaves by air currents, splashing rains, tools and so on. When the spores land on susceptible onion tissue they germinate in a film of water, and the germ tubes penetrate the stomata or penetrate directly through the epidermis. Early symptoms can appear within 1 to 4 days after penetration has occurred. A new generation of conidia may be produced every 5 days in warm, moist weather. Infection, reproduction and spread of the disease may follow in rapid succession as long as

Table 1. Contd.

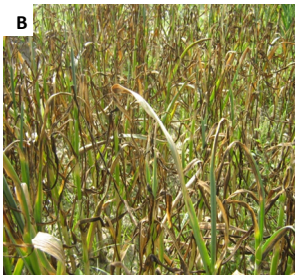
	favorable conditions persist. Free moisture, in the form of rain, persistent fog, or dew, is required for infection and spore production. Mycelial growth of the fungus occurs over a temperature range of 6° to 34°C (optimum 25° to 27°C) at a relative humidity of 90 percent. Onion bulbs become infected at harvest or later in storage through the neck or through wounds in the fleshy bulb scales. The rot is first semi watery and a deep yellow but gradually turns a wine-red, finally becoming dark brown to black.
Management strategies	Cultural methods include long rotations with non related crop and good drainage brings down the incidence of the disease. i. Lowering the density of transplanted crops causes reduced infection. ii. Avoid excess doses of nitrogenous fertilizers. iii. Use of resistant/tolerant varieties. iv. Frequent and judicious application of fungicides reduces the incidence of purple blotch
Figures/captions	  **Figure 1.** (a) Onion and (b) Garlic crop affected with purple blotch disease.
Name of disease	**Stemphylium blight**
Causative agent	*Stemphylium vesicarium* (Wall.) Simmons
Area and distribution	It infects herbaceous plants such as onion, garlic, asparagus, lucerne, tomato and soybean and trees also, that is, pear, mango etc. The fungus produced significant damage alone and in a complex with *Alternaria porri*. In some fields, foliage losses of 80 to 90% have been recorded.
Symptomatology	The symptoms that develop on each host are quite different. Initial symptoms appear on the leaves as brown spots, often surrounded by a purple halo. In garlic and onion, infection usually remains restricted to the leaves and does not extend to the bulb scales. Symptoms on pear are visible from blossom to ripening and are characterized by necrotic spots on the leaves and young stems, and brown spots surrounded by a red-purple halo on the fruits. Lesions on fruits are mainly located at the blossom end. Infections progress internally through the fruit causing its maceration. On garlic, two types of leaf lesions can be observed such as small white spots and progressing purple spots (with sunken tissues). These lesions may be found simultaneously and are associated with large, necrotic areas progressing along the leaf. If the infection is severe, necrosis is observed in all aerial plant organs and the plant desiccates. On onion, initial infections on the leaves produce small, light-yellow to brown, water-soaked lesions. As the lesions expand, they coalesce, causing extensive blight of the leaves. The centre of the lesions turn brown and finally black as the fungus sporulates.
Management strategies	i. Reduced plant density and good field drainage significantly reduced the disease incidence. ii. Avoid excess doses of nitrogenous fertilizers. iii. Use of resistant/tolerant varieties. iv. Judicious application of fungicides reduces the incidence of disease.
Figures/captions	  **Figure 2.** (a) Onion and (b) garlic crop affected with stemphylium blight disease.

Table 1. Contd.

Name of disease	**Downy Mildew**
Causative agent	*Peronospora destructor*
Area and distribution	Downy mildew is a destructive and widely distributed disease of bulb crops. Due to this disease, considerable losses of bulbs and seed production of onion crops have been reported. The pathogen and disease was first described by Berkley in 1841.
Symptomatology	Downy mildew caused by *P. destructor* may cause local infections on onion leaves or be systemic and infect the entire plant. Additional hosts of the fungus include Egyptian onion, the potato or multiplier onion, Welsh or Spanish onion, chives, garlic, leek, shallot, and possibly other species of *Allium*. Red onions have resistance to some extent. The disease is reported from northern hilly track and plains particularly in high humid locations. The disease is worst in damp conditions and late planting of the crop, application of higher doses of fertilizers and numerous irrigation increased disease severity. Symptoms appear on the surface of leaves or flower stalk as violet growth of fungus, which later becomes pale greenish yellow and finally the leaves or seed stalks collapse.
Management strategies	i. Onion bulbs used for seed crop should be exposed to sun for 12 days to destroy the fungus. ii. Avoid application of higher doses of fertilizers and frequent irrigation. iii. Timely sowing of bulbs also reduces the severity of the disease. iv. Foliar spraying of Zineb (0.2%), Karathane (0.1%) or Tridemorph (0.1%) also gives good control of the disease.
Name of disease	**Basal Rot/Bottom rot**
Causative agent	*Fusarium oxysporum f. sp. cepae* W. C. Snyder and H. N. Hansen
Area and distribution	It is present in most parts of the world wherein onions are being grown. There can be up to 90% loss of seedlings (Barnoczkine, 1986), yields of susceptible cultivars can be halved, and there can be a 30% loss in store. Seed yield is also reduced (Davis and Reddy, 1932). The disease causes serious losses in garlic also. The disease incidence is more in the area where onion and garlic crop is grown continuously. A moderate temperature of 22 to 28°C favours disease development.
Symptomatology	An initial symptom of the disease is yellowing of leaves and stunted growth of plant and later on, the leaves dry from tip downwards. In early stage of infection, the roots of the plants become pink in colour and rotting take place later. In advanced stage, the bulb starts decaying from lower ends and ultimately whole plant die. Disease also appears during storage when the temperature (35 to 40°C) and relative humidity (70%) are high in the month of July to August.
Management strategies	i. Since the pathogen is soil borne, it is difficult to control disease. Mixed cropping and crop rotation reduce the incidence of disease. ii. Soil solarization by spreading polythene sheet of 250 gauges in summer season for 30 days reduces the infectious propagules, which in turn reduces the disease. iii. Seed treatment with Thiram (2 g/kg of seed) and soil application of Carbendazim, Thiophanate Methyl (Topsin-M) or Benomyl at 0.1% is effective in the controlling the disease. iv. Seedling dip in Carbendazim (0.1%) or with antagonist *viz. Pseudomonas cepacia* and *Trichoderma viride* significantly reduces the basal rot in onion crop. v. Application of *Trichoderma* spp along with arbuscular mycorrhizal fungi (AMF) at the time of transplanting of the crop.
Figures/captions	 **Figure 3.** Garlic bulbs are affected with *Fusarium* basal rot.

Table 1. Contd.

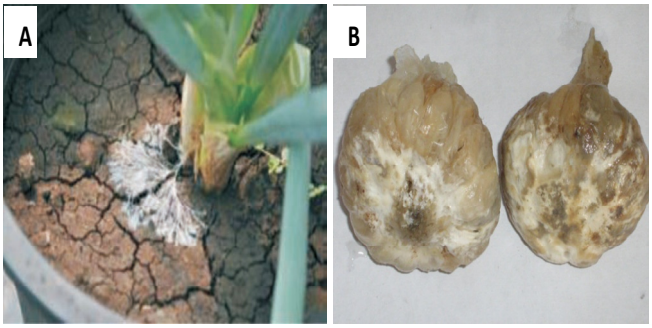
Name of disease	**White rot**
Causative agent	*Sclerotium cepivorum* Berk
Area and distribution	White rot is first reported in onion in the UK (Berkeley, 1841) and in garlic in Italy (Walker, 1924). The disease is now present in many areas of the world where *allium* crops are cultivated and environmental conditions are favorable to the pathogen (Walker, 1924; Asthana, 1947; Adams, 1971).
Symptomatology	The initial symptom of the disease is yellowing and dieback of leaf tips. Scales stem plate and roots get destroyed. The bulbs become soft and water soaked. White fluffy or cottony growths of mycelium with abundant black sclerotia resembling mustard grain are seen on the infected bulbs.
Management strategies	i. Seed treatment with Thiram (2 g/kg of seed) and soil application of Carbendazim, Thiophanate Methyl (Topsin-M) or Benomyl at 0.1% is effective in the controlling the disease. ii. Seedling dip in Carbendazim (0.1%) or with antagonist viz. *Pseudomonas cepacia,* and *Trichoderma viride* significantly reduces the basal rot in onion crop. iii. Application of *Trichoderma* spp along with arbuscular mycorrhizal fungi (AMF) at the time of transplanting of the crop.
Figures/captions	 **Figure 4.** (a) Onion plant (b) garlic bulb affected with white rot.
Name of disease	**Onion smut**
Causative agent	*Urocystis cepulae* Frost
Area and distribution	This disease is first reported from United States in 1850 and is probably present in most *Allium* growing areas. The smut fungus survives as spores in the soil for many years.
Symptomatology	The disease occurs in areas where temperature remains below 30°C. Since the fungus remains in soil, disease appears on the cotyledon of the young plant soon after it emerges. Smut appears as elongated dark, slightly thickened areas near the base of seedlings. The black lesions appear near the base of the scales on planting. The affected leaves bend downwards abnormally. On older plants, numerous raised blisters occur near the base of the leaves. The lesions on plant at all stages often expose a black powdery mass of spores.
Management strategies	i. Crop rotation with other vegetable crops reduces the incidence of the disease. ii. Treating the seeds with Captan or Thiram at 2.5 g/kg of seed before sowing controls the disease. iii. Seed bed treatment with Methyl Bromide (1 kg/25 m^2) is effective in controlling the disease.
Name of disease	**Black mold**
Causative agent	*Aspergillus niger*
Area and distribution	Black mold is the most important post-harvest disease under hot climates. In India, it is very common wherever onion and garlic is stored (Gupta and Srivastava, 1992).
Symptomatology	The disease is common in onion and garlic stored in hot climates where the temperature ranges between 30 to 45°C. It is characterized by the black powdery mass of spores that appear on the exterior of the scales. The black spore masses are also seen on inner scales. It reduces the market value of the bulbs.
Management strategies	i. For effective control of disease, bulb should be left for drying in the field for two days. These bulbs should be further dried in shade for 10-15 days before storage. ii. Care should be taken to avoid injury to the bulbs during post harvest handling. iii. The crops should be sprayed with Carbendazim (0.2%) 10-15 days before harvesting.

Table 1. Contd.

Name of disease	**Anthracnose/Twister /Seven curl disease**
Causative agent	*Colletotrichum gloeosporiodes*
Area and distribution	Onion twister disease, anthracnose or seven curl disease is reported to be widespread throughout the world but more usual in the tropics and subtropics. It is a facultative parasite wide host range.
Symptomatology	The symptoms appear initially on the leaves as water soaked pale yellow spots, which spreads lengthwise covering entire leaf blade. The affected leaves shrivel and droop down.
Management strategies	i. Since the pathogen survives on crop debris, sanitation and destruction of infected crop debris helps in reducing the disease. ii. Use of Mancozeb (0.25%), Carbendazim (0.1%) or Thiophanate Methyl (0.1%) as foliar spray is effective against the disease. iii. Application of bio-control agents like *Trichoderma viride* to the soil reduces the disease inoculum.
Name of disease	**Pink root rot**
Causative agent	*Phoma terrestris*
Area and distribution	Disease is first reported in Texas in 1917 but had been important for at least last 20 years (Hansen, 1929). In India, it was reported by Mishra et al. (2012). The disease is present in areas with high soil temperatures, and mainly affects onion and garlic. Pink root often occurs in association with *Fusarium* basal rot. In these circumstances, it may be difficult to determine the relative importance of each disease.
Symptomatology	Pink root rot commonly occurs on onion roots of under matured plants in poorly drained areas. The typical symptoms are light pink to yellowish brown discoloration on roots that becomes dark pink and then eventually purple colour in advanced stages of the disease. Diseased roots eventually shrivel, become brittle and die. Below ground, symptoms are pink to deep carmine root leading to necrosis and a reduction in total root mass (Figure 1). The conidium is hyaline and single celled and upon germination it produces hyphae that penetrates young roots and grows through the cortical tissues. The fungus produces minute, black almost globose fruiting bodies (pycnidia) in the epidermal and cortical cells with size of 3.9-5.8 x 2-2.3 µm.
Management strategies	i. Long rotations of 3 to 6 years with crops not susceptible to the pathogen will reduce but not eliminate the occurrence of disease. ii. Some onion cultivars possess resistance to the pathogen and should be planted in fields with a history of pink root. iii. Fumigation with chloropicrin is effective but costly. iv. Soil solarization during the nursery raising.
Name of disease	**Neck rot**
Causative agent	*Botrytis allii*
Area and distribution	Neck rot of onion, garlic and shallot is one of the major bulbs destroying diseases which are caused by *Botrytis allii, B. squamosa and B. cinerea*. The fungus usually infects mature plants through the neck tissues or through wounds in the bulbs.
Symptomatology	Symptoms are first seen as a softening of the tissues around the neck of the bulb, or more rarely, at a wound. A definite margin separates diseased and healthy tissues. Infected tissues become sunken, soft and appear brownish to grayish in color, as if they had been cooked. These symptoms progress gradually to the base of the bulb. In a humid atmosphere, a grey felt like mold later forms on the rotting scales. Often, the outer scales of the bulb need to be removed before the mold can be seen. Hard, irregularly shaped kernel-like bodies, sclerotia, may form between scales, especially at the neck region. White at first, these turn black with age; they vary from $^1/_8$ to $^1/_4$ inch in size. The neck area becomes sunken and dried out; the entire bulb may become mummified. Secondary invasion by soft rot bacteria causes a watery rot.
Management strategies	i. The most common point of infection is through the exposed succulent tissue when plants are topped before they have dried sufficiently. A combination of several of the following cultural procedures should reduce losses. ii. Plant varieties that mature properly so neck tissues are dry before storage. Generally colored varieties are more resistant than white varieties.

Table 1. Contd.

	iii. Do not apply nitrogen fertilizer after mid-July and be sure that slow release nitrogen fertilizers are not applied too late in the season. iv. As harvest time approaches discontinue irrigation to allow tops to dry down. v. Allow tops to mature well before harvest. vi. Undercut and windrow onions until inside neck tissues are dry before topping and storing. Do not store improperly cured bulbs.
Name of disease	**Sour skin**
Causative agent	*Pseudomonas cepacia* (Burkholder) Palleroni and Holmes
Area and distribution	It is first described in 1950, has been reported from onion-growing areas all over the world. Losses often appear in stored onions, but infection usually begins in the field. The disease can be serious in individual fields, with yield losses of 5–50%. Sour skin is primarily a disease of onions, but other *Allium* species are reported to be hosts.
Symptomatology	Primary symptoms on onions include a slimy (but initially firm), pale yellow to light brown decay and breakdown of one or a few inner bulb scales. Adjacent outer scales and the center of the bulb may remain firm. Externally, bulbs appear sound, but the neck region maysoften after leaves have collapsed. In advanced stages, healthy scales can slip off during handling. Young leaves some times die back, starting at the tips. Bacterial cells are rods that measure 1.6-3.2 × 0.8-1.0 µm; they occur singly or in pairs; and they are motile by means of tufts of polar flagella. Most strains produce non-fluorescent, yellowish or greenish pigments, but the pigments may be of a variety of colors. *P. cepacia* is an obligate aerobic bacterium. The optimum growth temperature is 30–35°C. No growth occurs at 4°C, and most strains grow at 41°C. Denitrification is negative while nitrate is reduced to nitrite. It is oxidase positive and arginine dihydrolase negative and can liquefy gelatin.
Management strategies	i. Control measures include proper maturing of the crop and quick drying after topping and harvest. ii. Since contaminated irrigation water has been implicated in the spread of the pathogen, the use of recycled or irrigation runoff water should be avoided. iii. The method of irrigation has a substantial impact on the incidence of sour skin. Season-long overhead irrigation provides a favorable environment for infection by *P. cepacia*, whereas furrow irrigation results in almost complete absence of the disease. In experimental plots, the final four or five sprinkler irrigations were accompanied by increases in sour skin of 150–300%. iv. Where sour skin is a potential problem, changing from sprinkler to furrow irrigation, at least from bulbing to the end of the season, is advisable where feasible.
Name of disease	**Bulb canker/Skin blotch**
Causative agent	*Embellisia allii* (Campan.) E. G. Simmons
Area and distribution	It is a major problem of onion and garlic during storage.
Symptomatology	The initial symptom of the disease was grayish spots on the outer scales of the bulb, later becoming enlarged and covering the entire bulb with a dark, blackish colour (Figure 1a, b). Colonies on PDA were effuse, grey to brown to black, with diameters averaging 30 mm after five days at 22°C. Microscopic observations revealed chlamydospores (Figure 2A), dark brown to black, forming abundantly on the host, variable in shape and size, up to 100 to 120 µm long and 3 to 5 µm wide. Conidia (Figure 2B) were generally smooth, obovoid or ellipsoidal, rounded at the ends, 20-50 x 7-10 µm, mid- to dark-brown to black, with generally two to five (maximum six) thick, very dark transverse septa, and occasionally one or two oblique or longitudinal septa
Management strategies	i. Proper curing and drying is essential before storage. ii. Fungicide applications during the season and especially prior to harvest may reduce the incidence of neck rot. However, fungicide applications cannot overcome improper cultural or storage practices. iii. Cure onions with forced, heated air at 80-95 F (27-35°C) for a few days at the beginning of the storage period. iv. As harvest time approaches discontinue irrigation to allow tops to dry down.

Table 1. Contd.

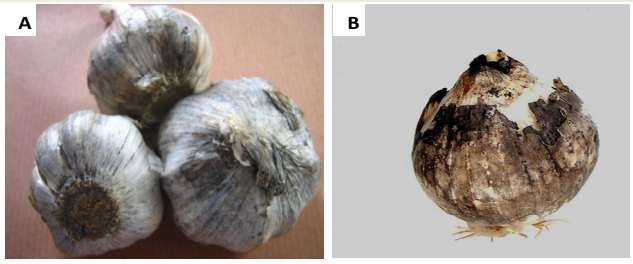
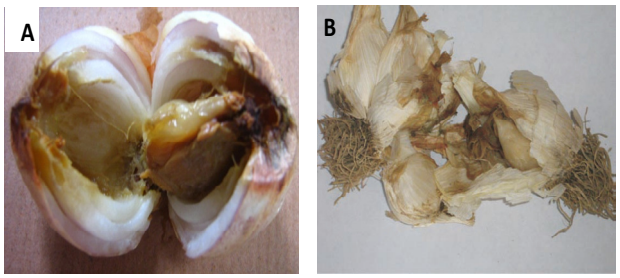
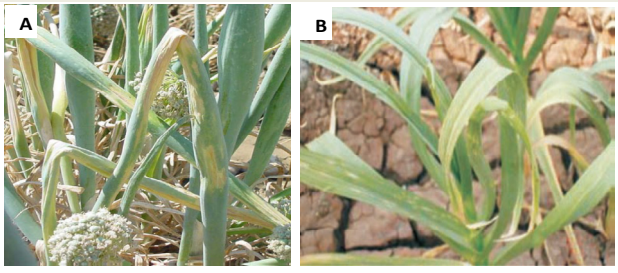
Figures/captions	 **Figure 5.** (a) Garlic (b) Onion bulbs affected with bulb canker.
Name of disease	**Bacterial Brown Rot**
Causative agent	*Pseudomonas aeruginosa*
Area and distribution	It is caused by bacterium *Pseudomonas aeruginosa*
Symptomatology	It is very serious disease of onions in storage. The infection occurs through the wounds. The rot begins at the neck of the bulbs which later gives foul smell through the neck when squeezed.
Management strategies	i. Proper curing and rapid drying of the bulbs after harvesting is essential for controlling the disease. ii. Affected bulbs should be discarded before storage. iii. If rains occur during maturity, spraying of Streptocycline (0.02%) is recommended.
Figures /captions	 **Figure 6.** (a) onion (b) garlic bulbs affected with bacterial rot.
Name of disease	**Iris yellow spot virus (IYSV)**
Causative agent	Virus
Area and distribution	IYSV previously reported in Netherland, Israel and Brazil. First reported in US in Idaho in 1991, now it is worldwide. It is caused by *Gemini* virus.
Symptomatology	Plants infected with IYSV will have characteristic yellow- to straw-colored lesions. Lesions may be more or less round with or without a necrotic center or may be diamond shaped (Figure 1). Lesions will appear on both the seed stalk and the leaves. Seed stalks may swell at the point of infection. Late in the season, infected seed stalks and leaves will lodge (fall over).
Management strategies	i. Removal and destruction of the diseased plants checks the spread of the disease. Healthy bulbs should be used for seed production. ii. Spraying of Decis (0.1%), Malathion (0.1%) or Metasystox (0.1%) to control the vectors checks further spread of the disease.
Figures/captions	 **Figure 7.** (a) onion (b) garlic plants affected with IYSV.

Table 1. Contd.

Name of disease	**Onion Yellow Dwarf Virus (OYDV)**
Causative agent	Virus
Area and distribution	This is a viral disease caused by onion yellow dwarf virus. It can be transmitted either mechanically or by insect vectors. Onion yellow dwarf virus, a member of the genus poty virus in the family potyviridae, is a filamentous virus containing a single, positive sense genome RNA. OYDV is transmitted by Aphids in a non-persistent manner.
Symptomatology	The symptoms of the disease are severe stunting of the plants, dwarfing and twisting of the flower stalk. The affected leaves and stems change their normal green colour to various shades of yellow and leaves tend to flatten and crinkle and as a result bend over.
Management strategies	i. Removal and destruction of the diseased plants checks the spread of the disease. ii. Healthy bulbs should be used for seed production. iii. Spraying of Decis (0.1%), Malathion (0.1%) or Metasystox (0.1%) to control the vectors checks further spread of the disease.
Name of disease	**Root-knot nematode**
Causative agent	*Meloidogyne* spp
Area and distribution	Root-knot nematodes are major pathogens of vegetable crops throughout the world, impacting both the quantity and quality of marketable yields. In addition, root-knot nematodes interact with other plant pathogens, resulting in increased damage caused by other diseases. In case of bulb crops, the weight of bulb onions may be reduced by as much as 50 to 70% in heavily infested fields at an infestation level of 20 eggs/cc soil. Recently Mishra et al. (2010) first time reported occurrence of *Meloidogyne graminicola* on onion from India.
Symptomatology	Affected crops show stunted growth, yellowing of the leaves, smaller bulbs, delayed maturity, wilting of the plants despite adequate soil water content. Severely infected seedlings produce few roots and usually die rapidly. Heavy infection of older plants causes the plants to wilt unexpectedly and die off early. Swelling or galls, develop on the roots of infected plants, as the result of nematode-induced expansion of root cells. All the root-knot galls damage the vascular tissues of roots and thus interfere with the normal movement of water and nutrients through the plant. They also increase the susceptibility of the root system to invasion by disease causing fungi and bacteria.
Management strategies	i. Grow seedlings in nematode free soil and test of soil for nematodes before planting in fields. ii. Use of crop rotation. Do not plant susceptible crops repeatedly in some areas. iii. Summer fallowing, in which all vegetation is kept off the infested area, is a cheap and effective way to reduce nematode numbers. This will not stop nematode eggs from hatching but without food plants, the young worms will die. iv. Practice of soil solarization. Solarization involves covering raised and moist beds with clear plastic for 2 to 4 months during the hottest months of the year. The increased soil temperature helps to kill many soil borne pests and pathogens including root-knot nematode. Nematodes in these moist beds will hatch out from eggs, move around for roots and will die of starvation. v. Organic amendment. Beneficial microorganisms are in high numbers in soil amended with different organic matters. Some beneficial fungi and bacteria are parasites of nematode eggs and also prey on nematodes. The parasitized eggs do not hatch and thus populations are reduced. Organic amendments enhance biological suppression of parasitic nematodes in soil
Figures /captions	 **Figure 8.** Onion bulb affected with root knot nematode.
Name of insect/pests	**Thrips**
Causative agent	*Thrips tabaci*
Area and distribution	i. Thrips are spread worldwide. ii. These are important pests of onions, garlic, and several other crops in most parts of the world.

Table 1. Contd.

	iii. Thrips can colonize crops from sea level up to 2000 m above sea level. iv. They can be a problem in several other crops such as chilli, capsicum, cabbage, cotton, celery, tomato, beans, cucumber and pineapple. v. Thrips can be found in almost any cultivated and weedy plants.
Symptomatology	A reliable treatment threshold has not been developed; however, a threshold of 30 thrips per plant during mid-season has been considered. For small onion producers, the recommended economic threshold is 20% of plants infested with thrips. The threshold is three thrips per green leaf. The cumulative thrips-days are 500 to 600 (that is, 50 to 60 thrips for 10 days).
Management strategies	i. Colour-sensitive mulch: aluminium-coated mulch repels pest by 33 to 68%. ii. Intercropping with maize and carrot may also reduce thrips population. iii. Lack of adequate soil calcium may invite higher population of thrips. iv. High nitrate levels invite thrips. v. Irrigation of onions is very important to control thrips. vi. Use sprinkler irrigation to simulate rainfall and control thrips. v. If onion plants encounter water stress, damage by thrips may be magnified because the plants lose large amounts of water from the damaged tissue. vi. It is very important that onion seedlings are clean of thrips before transplantation. vii. Spraying of Deltamethrin at 1 ml/L gives best performance. viii. Fipronil at 1 ml/L of water and spionsad at1 ml/L of water offer best control of this pest. ix. At high temperature, profenophos at 2 ml/L gives good control. x. Alternately use chemical groups. xi. Spinosad is a recently discovered insecticide, derived from the fermentation of actinomycetes bacteria, commonly found in soil. xii. The National Organic Board has recommended that Spinosad be allowed in organic production.
Figures /captions	  **Figure 9.** Onion plant showing infestation of thrips.
Name of insect/pests	**Onion maggot**
Causative agent	*Delia antique* Meigen *D. Platura*
Area and distribution	i. Maggot is an onion pest and does not generally cause economic damage to garlic. ii. Onion maggot can cause losses from 20 to 90% in temperate regions.
Symptomatology	i. Onion maggot adults are one-fourth of an inch, gray brown, bristly, humpbacked flies. ii. Eggs are white and elongated with characteristic surface ridging and hexagonal pattern. iii. The one-third of an inch maggots are legless, cylindrical, tapering at the head, and creamy white. They pupate with in a chestnut brown puparia. iv. These flies lay eggs in small batches on the soil surface near the base of seedlings. Female mates only once, but males are capable of repeated mating. Maggots prefer soils heavy in organic matter where they can survive and move to seeds.
Management strategies	i. Avoid planting in soils that are high in undecomposed matter. ii. Avoid planting where crop rotations are not followed. iii. Employ biological control. iv. No promising natural enemies exist, which can be successfully employed for control of this pest at field level. v. Only braconid, *Aphaereta pallipes*, *Staphylinid,* and *Aleochara bilineata* have significantly increased the mortality of onion maggot, but the performance in field is poor. vi. Ground beetle is an onion maggot predator, and establishing grassy refuse stripes in an onion crop enhances beetle population and reduces maggot population.

of other species variously referred to as onions and cultivated for food, such as the Japanese bunching onion (*Allium fistulosum*), Egyptian onion (*Allium proliferum*) and Canada onion (*Allium canadense*). There are over 600 species of *Allium*, distributed throughout Europe, North America, Northern Africa and Asia. The bulb of onion consists of swollen bases of green foliage leaves and fleshy scales. These bulb crops are rich in minerals like phosphorous, calcium and carbohydrate. It also contains proteins and Vitamin C.

CHEMICAL COMPOUNDS OF ONION AND GARLIC

The pungency in onion and garlic is due to allyl-propyldisulphide and alinase. Onions contain chemical compounds with potential anti-inflammatory, anticholesterol, anticancer and antioxidant properties, such as quercetin (Slimestad et al., 2007). It has also been reported that garlic extract inhibited vascular calcification in human patients with high blood cholesterol (Durak et al., 2004). The known vasodilative effect of garlic is possibly caused by catabolism of garlic-derived polysulfides to hydrogen sulfide in red blood cells (RBCs), a reaction that is dependent on reduced thiols in or on the RBC membrane. Hydrogen sulfide is an endogenous cardioprotective vascular cell-signaling molecule. The fungicidal and insecticidal properties of onion and garlic are also well identified. *In vitro* studies have revealed that onion and garlic possesses antibacterial, antiviral and antifungal activity.

CULTIVATION OF ONION AND GARLIC

In India, onion and garlic have been under cultivation for the last 5000 years. As per FAO (FAOSTAT, 2010), onion is grown in 0.8 million hectares with production of 8.2 million tones and productivity of 101.6 q/ha whereas, garlic is grown in 0.015 million hectares with production of 0.65 million tones and productivity of 43.2 q/ha in India. Maharashtra is the leading state in onion production followed by Uttar Pradesh and Orissa whereas Madhya Pradesh is the major garlic producing state, followed by Gujarat and Uttar Pradesh (Anonymous, 2010). India ranks second to China in area and production in both onion and garlic, but ranks 102nd for onion and 74th for garlic in terms of productivity (FAOSTAT, 2010).

PRODUCTION OF ONION AND GARLIC

Production and productivity not only depends upon area and cultural practices but also on genotypes, environment, several diseases and insect pests that affect the crop during entire cropping period. There are a number of pathogens and insect pests that attack onionsand garlic plants throughout their developmental stages and significantly reduce the crop yield. The present manuscript deals with management of major bacterial, fungal, viral and nematode diseases and insect pests of onion and garlic with an emphasis for which effective diseases and insect pests management systems have been put into practice. Brief descriptions of the symptoms are included to assist in identification of the specific diseases and insect pests (Table 1).

Conflict of interests

The authors have not declared any conflict of interests.

REFERENCES

Anonymous (2010). National Horticultural and Research Development Foundation (NHRDF) Database. Available at http://www.nhrdf.com/contentPage.asp?sub_section_code=115

Asthana RP (1947). Studies on Sclerotium-forming fungi I. Sclerotium cepivorum Berk. and S. tuliparum Klebahn. Part 2. Symptoms, mode of infection and host range. Proc. Indian Acad. Sci. Section B 26:108-116.

Barnoczkine S (1986). Possibilities to control Fusarium on onion. Zoldsegtermesztesi Kutato Intezet Bulletinje 19:33.

Davis GN, Reddy CS (1932). A seedling blight stage of onion bulb rot. Phytopathology 22:8.

Durak I, Kavutcu M, Aytaç B (2004). Effects of garlic extract consumption on blood lipid and oxidant/antioxidant parameters in humans with high blood cholesterol. J. Nutr. Biochem. 15(6):373-377. http://dx.doi.org/10.1016/j.jnutbio.2004.01.005

FAOSTAT (2010). Available at: http://faostat.fao.org/faostat/ collections http://dx.doi.org/10.1016/j.jnutbio.2004.01.005

Hansen HN (1929). Etiology of the pink root disease of onion. Phytopathology 19:691.

Mishra RK, Singh S, Pandey S, Sharma P, Gupta RP (2010). First report of root knot nematode Meloidogyne graminicola on onion in India. Int. J. Nematol. 20(2):236-237.

Slimestad R, Fossen T Vågen IM (2007). Onions: A source of unique dietary flavonoids. J Agric. Food Chem. 55(25):10067-10080. http://dx.doi.org/10.1021/jf0712503

Walker JC (1924). White rot of Allium in Europe and America. Phytopathology 14:315-323.

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Performance evaluation of indigenous Arabica coffee genotypes across different environments

Yonas Belete[1]*, Bayetta Belachew[2] and Chemeda Fininsa[3]

[1]Jimma Agricultural Research Center, P. O. Box, 192, Jimma, Ethiopia.
[2]Inter Africa Coffee Organization (IACO), Abidjan, Ivory Coast.
[3]Haramaya University, P. O. Box 138, Dire Dawa, Ethiopia.

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Evaluation of 30 Arabica coffee genotypes was carried out at four different locations in south-western Ethiopia to identify genotypes that exhibits stable performance across wide environments. The analyses of variances revealed that yield differences among genotypes were highly significant at all locations in both seasons except at Jimma during the second season. The interaction was also highly significant. Six genotypes: 8211, 808, 8219, 75187B, 8143 and 8213 exhibited higher overall mean yield that ranged from 1217 to 1633 kg of clean coffee per hectare at the first two bearings. Such mean yield is very high as climax yield in Arabica coffee is attained starting from the fourth bearing stage. However, only three of these genotypes: 8213, 8143 and 75187B exhibited superior performance consistently at all locations irrespective of the interaction. The result of the trials is considered as one remarkable success in the history of Arabica coffee research as identifying genotype that exhibits stable performance across wide environments has long been a major challenge and in practicable for decades.

Key words: Agro-ecologies, Arabica coffee, environments, indigenous, genotypes.

INTRODUCTION

Arabica coffee is an important crop in the national economy of Ethiopia. About 25% of the people in the country in one way or the other derive their livelihood from coffee. Depending on prices on world market the share that comes from coffee still constitutes 25 to 40% of the national export (Behailu et al., 2008; Nigussie et al., 2008). Furthermore, the land covered with coffee in Ethiopia currently is very substantial and is estimated to range from 400,000 to 650,000 the average being 550,000 ha.

Despite the role coffee plays in the national economy and in spite the country is origin of Arabica coffee, average national productivity has not exceeded six quintals (Jefuka et al., 2012; Eshetu et al., 1999; Workafes and Kassu, 1999). This is very low in contrast to yield levels reported usually in some Latin American countries. The factors attributed to such low productivity include lack of resistant varieties to various diseases and insect pests, and poor agronomic practices (Eshetu et al., 1999; Workafes and Kassu, 1999). Lack of stable varieties that exhibit wide adaptation across wide ranges of environments is also another factor attributed to the low

*Corresponding author. E-mail: yonasbelete85@yahoo.com, Tel: 251-928 26 50 82; Fax: 251-047 111 19 99.

Table 1. Characteristics of test locations where the trials were carried out.

Location	Altitude	Latitude	Longitude	Temperature (°C)		Annual rainfall (mm)
				Min	Max	
Jimma	1753 m	7°36'5"	36°E	11.5	26.2	1531.8
Agaro	1600	7°9'	36.6E	NA	NA	NA
Gera	1940 m	7°7'	36°E	10.4	24.4	1878.9
Metu	1550	8°3'3"	36°E	12.5	28.6	1810.6

NA = Not available.

productivity of Arabica coffee in the country (Yonas and Bayetta, 2008). To identify stable varieties and thereby increase productivity of Arabica coffee in the country, Mesfin and Bayeta (1987) carried out series of adaptation tests across wide ranges of environments. The result of their study illustrated that a genotype that exhibits better adaptation at one location in one geographic region does not perform well at other locations of a contrasting region. Multi-location adaptation tests carried out in other countries also illustrated similar result that genotype-environment interaction is a common scenario in Arabica coffee genotypes like other crops (Agwanda et al., 1997). Related studies by Yonas and Bayetta (2008) in Arabica coffee and Montagnon et al. (2000) in *Coffea canephora* also illustrated significant interaction effects of genotypes across different environments. However, these workers illustrated the possibility of identifying varieties which could exhibit stable performance across wide environments. Since Ethiopia has both wide genetic diversity of Arabica coffee and diverse environments for growing it, conducting multi-locations adaptation tests across wide environments is important to identify stable genotypes which can increase productivity of Arabica coffee in the country.

Thus, the objective of the study was designed to identify stable genotypes that increase productivity of Arabica coffee across wide environments.

METHODOLOGY

Experimental sites

The trials were conducted at four different locations in southwestern region of Ethiopia: Jimma, Agaro, Metu and Gera. The first three locations represent medium altitude and Gera represents high land (Table 1).

Materials

The trials consisted of 30 pure lines Arabica coffee genotypes. They represent all the three types of canopy configuration: compact, intermediate or open. They were selected for their high potential for resistance to Coffee Berry Disease (CBD), yield and cup quality during a preliminary evaluation carried out at Gera. Primarily, they were collected from different farmers' field of southwestern region of the country along with quite large numbers of coffee accessions. The seeds (beans), which were used for preparing the seedlings, were prepared from representative bushes of each genotype. The beans were sown and raised in polythene bags for 10 months. Holes were dug and filled with topsoil before planting. The seedlings were field planted when they are approximately 10 months old in randomized complete block design of three replications. They were mulched in September immediately after planted. Each seedling was also protected from direct sunlight by small grass shelters starting from October until the normal rain in 2006 commenced. The shelters were removed when the normal rain after the dry months started. *Sesbania sesban* (temporary shade bush) were planted to provide regular shade over the plots. Each plot consisted of 10 bushes in single row. The spacing between rows and bushes within row were 2 × 2 m, respectively. The plots received uniform application of fertilizer and other cultural practices throughout the period of data collection. All coffee bushes were maintained on single stem pruning system. Yield was recorded in fresh cherry to the nearest 50 g from 10 bushes and converted to clean coffee bean yield per hectare. The mean clean coffee yield in kg/ha of the different genotypes was used for analysis. Over the course of time, some bushes had died so that by 2008/2009 and 2009/2010 some plots no longer had full 10 bushes stand. During analysis, the yield data of the plots with missing bushes were adjusted to represent a full stand of 10 bushes. The yield at harvest was multiplied by the ratio of the number of plants at the expected full stand to the number of plants harvested. No adjustment factor was used for the missing bushes as the orchards were at their first and second bearing and yield advantage for a plot with a poor stand compared to the one with a full stand is noticed only after the fourth bearings. The test materials are presented in Table 2.

Statistical analysis

First analyses of variance for clean coffee yield were carried out at the specific environments/location-year combinations using Agrobase software. Later, combined analysis of variance was carried out after confirming homogeneity error variances at the different environments to calculate environmental, genotypic and genotype by environment interaction effects. Since error variances at the different environments were homogenous, the pooled error mean square was used to calculate coefficient of variation (CV) and least significant differences for the combined means.

Analyses of variance of growth parameters for the different locations were also done. Phenotypic correlation between yield and growth characters was calculated as:

$$r_{pxy} = \frac{Cov_p(xy)}{\sqrt{\left(\sigma^2{}_p x \sigma^2{}_p y\right)}}$$

Where, r_{pxy} is phenotypic correlations coefficients between yield and

Table 2. The thirty arabica coffee genotypes evaluated at four different locations in south west Ethiopia.

S/No.	Genotype designation	S/No.	Genotype designation
1	74191	16	8011
2	75187-B	17	8017
3	7453	18	8019
4	74145	19	8021
5	75194	20	8112
6	7512	21	8133
7	7574	22	8136
8	7803-A	23	8143
9	7803-B	24	8144
10	7809-B	25	827
11	802	26	878
12	804	27	8211
13	808	28	8213
14	809	29	8219
15	8010	30	8223

growth characters; Cov_p is phenotypic variances of x and y, respectively.

RESULTS AND DISCUSSION

Coffee bean clean yield

The analyses of variances revealed that the differences among genotypes were highly significant for yield at Agaro, Gera and Metu in 2008/2009 and 2009/2010 and at Jimma in 2008/2009 only (Table 3). This indicates that there is real genetic difference among the different genotypes and improvement of yield by selection is possible. Similar result was reported by Mesfin et al. (2007), Bayetta et al. (2008), and Yonas and Bayetta (2008). However, the difference was non-significant at Jimma during the second year (2009/2010). The absence of yield difference during the second season could be attributed to the fact that genotypes usually exhibit less differentiation in less favorable environments. This is so because maximum phenotypic differentiation for any trait is expressed in optimum environments either from edaphic as well as the climatic points of view. Similar justification was reported for yield by Ariyo (1998) and for disease by Yonas (2014). Normally, in Arabica coffee, photosynthetic assimilates prior to the first flowering is totally used for vegetative growths. But in the later stages when coffee bushes start setting fruits, it moves to fill the developing fruits and undergoes vegetative growth. However, in unfavorable environments where either the edaphic or climatic conditions are sub-optimal, the balance of the assimilate movement could be disrupted where it may fully divert to the fruits if fruit buds are unproportionately heavy during the season and this restricts growth of secondary and tertiary branches which may bear fruiting buds for the next season. This is the root cause for alternate bearing or lack of irregularity of bearings of Arabica coffee or perennial crops in general over different seasons. The poor fertility status of the soil at Jimma was also reflected by stunted vegetative growths of plant heights, stem girths and canopy diameters ((Figures 1, 2 and 3).

The combined analysis of variance also revealed that mean square of genotypes, locations/environments, and genotype by environment interaction was highly significant (Table 4). However, regardless of the interaction genotypes: 75187B, 8143 and 8213 exhibited higher overall mean yields that ranged from 1355 to 1633 kg of clean coffee per hectare (Table 3). Such mean yield at the first two bearing is very high as climax yield in Arabica coffee is attained starting from the fourth bearing stage (Wrigley, 1988). The overall performance of these genotypes was also higher at all environments. This is in line with the work of Agwanda et al. (1997) and Yonas and Bayetta (2008) who reported the possibility of developing stable genotypes which can adapt across wide environments. But it disagrees with the earlier work of Mesfin and Bayetta (1987) who stated the difficulty of identifying stable genotypes that exhibit wide adaptation across wide environments. The disagreement between the two trials might attribute to differences of environmental diversity as it was more diverse in the former than the latter. This illustrates that it would be difficult to identify a genotype that exhibit stable performance across all locations over all geographic regions. But the result of the present study confirmed that it is possible to develop stable varieties for sub environments provided the coffee growing environments in Ethiopia are sub-divided into sub-geographic region. Such strategy can help to alleviate the problem of varieties inconsistent performance across very diverse

Table 3. Characteristic means of clean coffee yield (kilogram) per hectare of thirty Arabica coffee genotypes across four different locations in two seasons.

Genotype	Seasons								Combined mean
	2008/2009				2009/2010				
	Jimma	Agaro	Gera	Metu	Jimma	Agaro	Gera	Metu	
74191	447	868	965	1628	133	1013	920	986	870
75187B	1662	1457	1296	1905	299	1428	1656	1140	1355
7453	412	849	1001	1821	316	682	278	702	758
74145	886	1123	1518	2072	164	971	406	630	971
75194	726	927	1427	2385	256	758	528	344	919
7512	620	964	1281	1900	163	906	218	1176	903
7574	821	1685	1251	2428	155	224	761	243	946
7803A	952	1484	1340	2052	43	761	804	585	1003
7803B	936	1221	1219	1665	260	1048	1050	984	1048
7809B	684	1497	1496	1826	492	691	868	1056	1076
802	788	2115	1258	2196	216	849	755	358	1067
804	881	1822	718	1612	289	1049	562	61	874
808	816	1443	1995	2020	87	1201	764	1503	1229
809	935	1531	1209	2325	398	743	915	826	1110
8010	467	817	893	1652	261	858	668	855	809
8011	565	995	1110	1749	131	844	260	708	795
8017	569	969	1040	1716	293	904	623	600	839
8019	1010	2201	1045	1947	143	661	1488	749	1156
8021	929	1468	1388	1952	246	1133	576	404	1012
8112	981	1914	787	2492	326	946	870	412	1091
8133	465	1030	1241	1768	202	748	432	852	842
8136	733	1822	1590	1573	298	1008	552	365	993
8143	962	1827	2181	2280	184	1172	949	1473	1378
8144	730	2345	1206	1956	177	835	1034	852	1142
827	778	1686	1143	1597	436	887	599	942	1008
828	848	1525	1578	2005	172	1156	624	223	1016
8211	1006	2026	2614	2415	190	899	433	150	1217
8213	1218	2098	2763	3233	338	1497	883	1031	1633
8219	1111	2100	1741	1955	317	1235	1057	473	1249
8223	770	1547	1436	1665	343	685	999	126	946
Mean	824	1512	1391	1993	257	926	751	712	1046
CV	18.88	13.22	23.22	9.63	21	21.6	25	24.5	20.67
LSD 0.05	261	335	541	322	ns	335	315	292	332
LSD 0.01	352	452	730	434	ns	453	425	395	448

ns, Non-significant difference; LSD, least significant differences; CV, coefficient of variation.

environments and increase coffee productivity. Furthermore, the landscape system of the major coffee growing environments in Ethiopia is characterized by undulating and irregular terrain features and a coffee orchard on such landscape system may fall on either flat land or valley bottoms or sloping land of varying degree of intensity or on an environment that is favorable or less favorable from nutrient and/or moisture availability point of view or it may be on sloping land that faces different light intensities. These are potential variables which induce significant genotype by environment interaction and only genotypes with wide adaptation across such environments buffer yield stability. This is in line with the work of Cooper and Hammer (1996).

Twenty-five out of 30 genotypes exhibited equal or more yield at Metu or Agaro (medium altitudes areas) than Gera (higher altitude area) where the genotypes were planted at the fertile forest soil (Table 3). Similar studies carried out at low and mid altitudinal areas also revealed that the latter is more suitable for coffee fruit production than the former if other edaphic and climatic factors are kept not limiting (Mesfin and Bayetta, 1987;

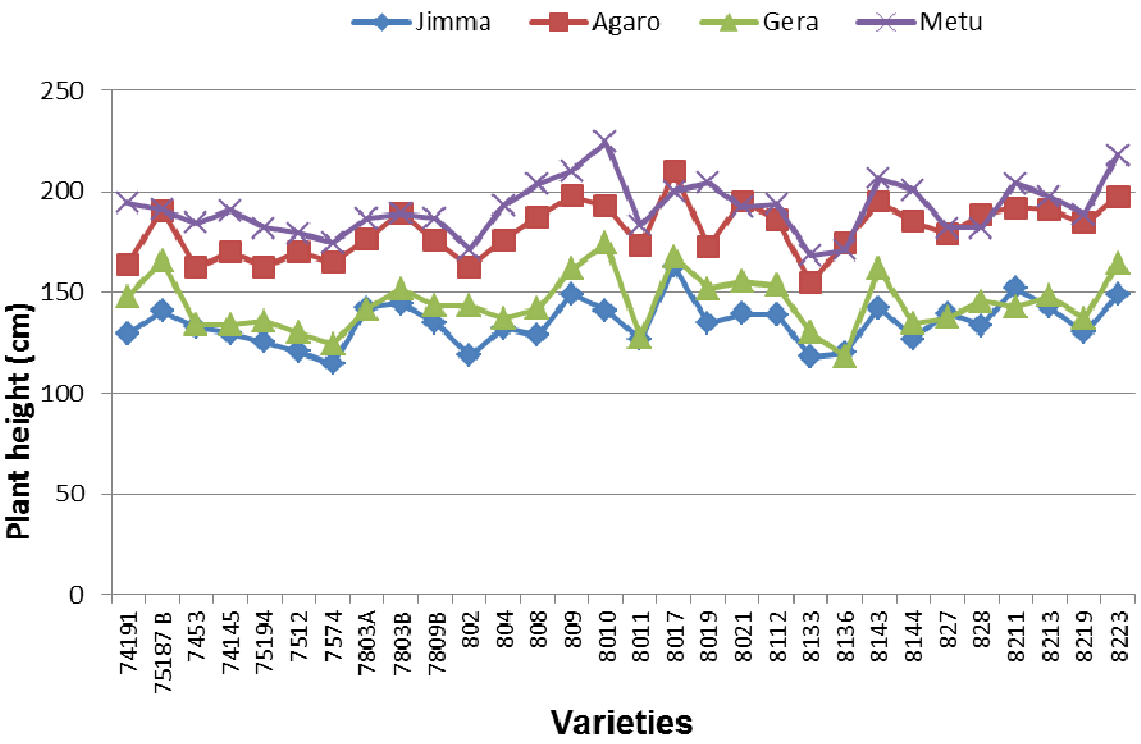


Figure 1. Characteristic means (cm) of thirty arabica coffee genotypes for plant height at four different locations: Jimma, Agaro, Gera and Metu.

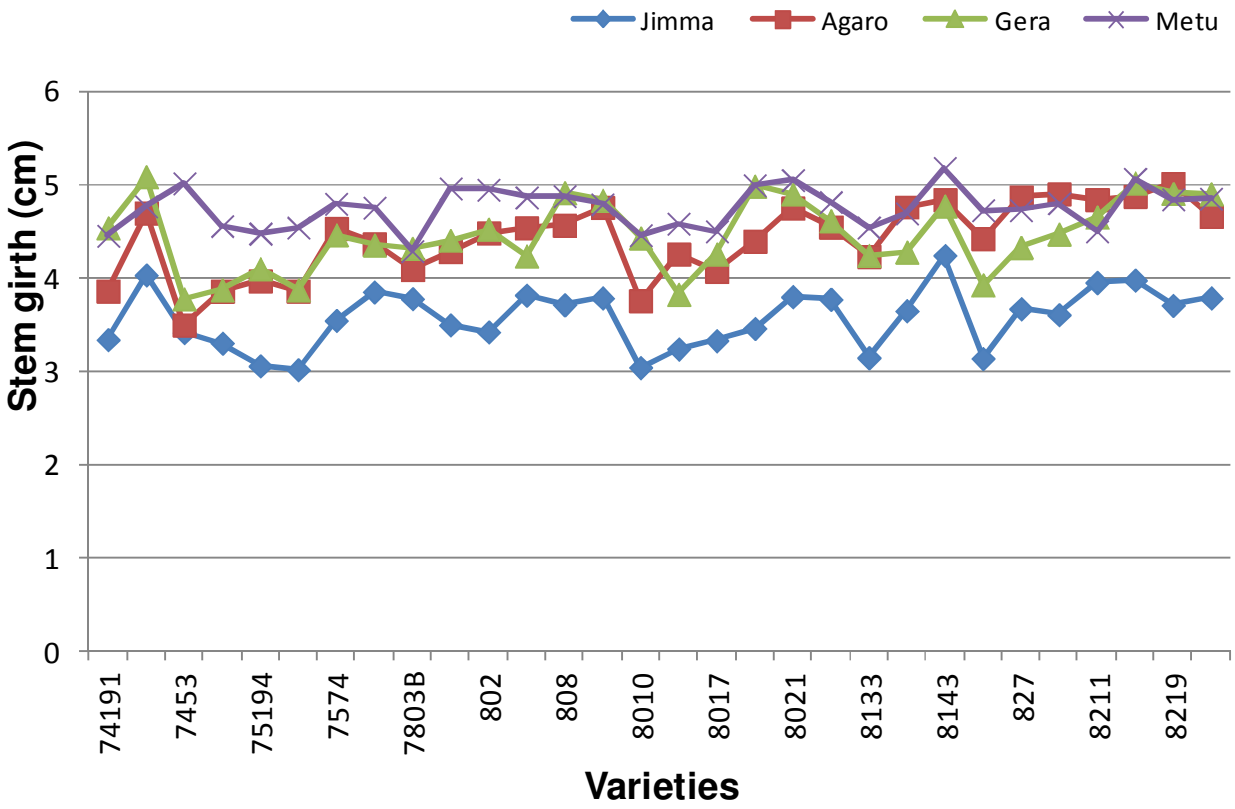


Figure 2. Characteristic means of thirty Arabica coffee genotypes for stem girth at Jimma, Agaro, Gera and Metu.

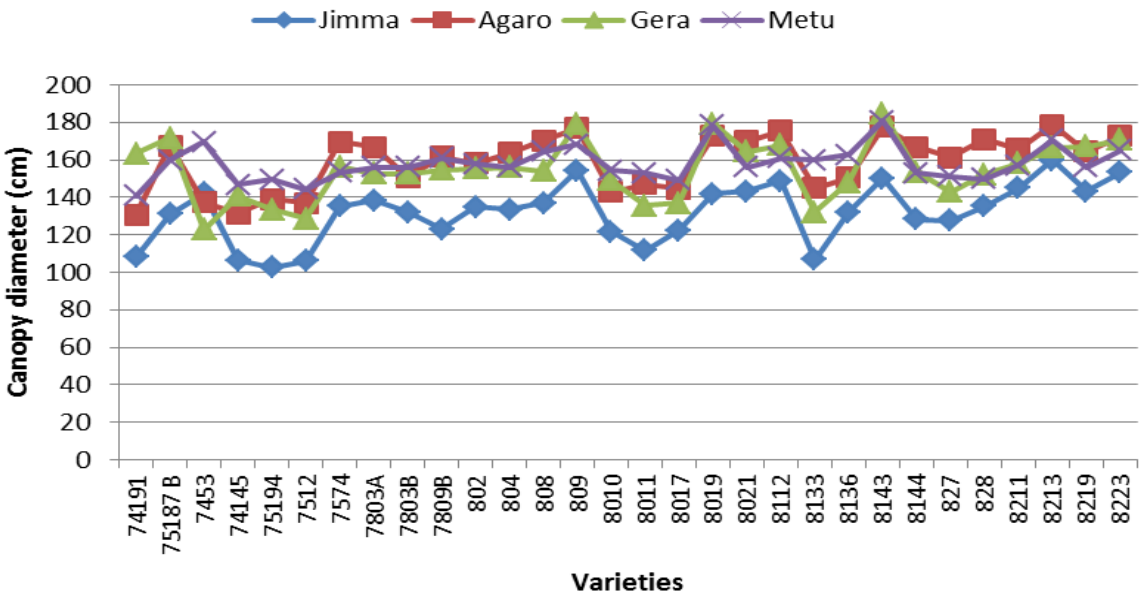


Figure 3. Characteristic means of 30 Arabica coffee genotypes for canopy diameter at Jimma, Agaro, Gera and Metu.

Table 4. Combined mean square of yield (kg) of thirty Arabica coffee genotypes evaluated across different environments.

Variance	Mean squares			
	Environments	Genotypes	G × E	Pooled error
DF	7	29	203	464
Clean yield	65268771**L	2572225.7**L	664704.7**	84945

**L, ** highly significant against mean square of G × E and mean square of error at 0.01 probability level.

Yonas and Bayetta, 2008). Probably the temperature at medium altitude areas could be more conducive for different ion of flower buds to fruiting flower than leaf at medium altitude areas than either high or low altitude areas to bear more fruits and result in higher yield performance.

It was also noticed from the table that selection of genotypes at the favorable environment of Gera favored those genotypes that respond favorably at similar environments of Agaro and Metu but not at Jimma. This indicates in general that genotypes selection at favorable or less favorable environments favors to select those genotypes which respond favorably at the respective environments only. This indicates the merit and demerit of conducting preliminary variety trial on either favorable or unfavorable environments to advance suitable variety to the type of environment in question. However, there are genotypes which exhibit linear response across wide environments. But to identify such genotypes, either the preliminary evaluation should be done in contrasting environments: one favorable and the other less favorable so that those genotypes which exhibit better performance in both environments could exhibit stable performance across wide environments or the selection intensity during the preliminary evaluation at any given environment should be low to advance large number of genotypes for the subsequent multi-location adaptation tests and identify the genotypes which exhibit wide adaptation. Similar justification was stated by Crossa (1990) and Basford and Cooper (1998) that genotypes should be tested across wide ranges of target environments before recommended for extensive use.

As a whole the yield obtained during the first season was much higher than the second (Table 3). Such imbalance in fruit setting over the two seasons is largely attributed to the very conducive environment prevailed at all locations during 2007/2008 (Table 5). But the weather condition noticed during 2008/2009 was also conducive for vegetative growth and fruit production but the heavy fruiting noticed in the previous season restricted growth of fruit bearing branches that could set fruit in the following season. This subsequently reduced the yield in 2009/2010 season. This illustrates in general that analyzing stability of performance of Arabica coffee

Table 5. Monthly mean rain fall distribution (mm) of four different locations: Jimma, Gera and Metu during 2005, 2006 and 2007.

Year	Jimma			Gera			Metu		
	2008	2009	2010	2008	2009	2010	2008	2009	2010
Jan	16.4	102.5	29.8	13.8	86.2	30	0	19.1	0
Feb	10.7	5.9	49.9	78.5	9.2	91.7	19.3	3.9	38
Mar	70.9	103	79.5	114.7	179	169.1	28.3	45.9	87.7
Apr	75	86.2	133.1	146.7	99.3	219.5	52	81.1	43.9
May	237.7	76.3	17.2	253.7	204	59.2	188.4	90	79.9
June	236.3	316.3	272.2	318.5	308	319.9	294	295	365.6
July	281.6	150.3	190.6	265.3	151	281.8	265.6	111	225.2
Aug	186.7	219.8	210.8	255.7	219	207	484.1	260	252.9
Sep	202.9	196	235.9	294.7	293	337.3	228.1	219	340.9
Oct	214	56.5	88.8	298.3	118	62.5	179.1	100	142
Nov	58.9	9.1	14.1	29	37.9	84.9	29.4	28.5	29.8
Dec	4.6	128	26.1	37.1	52.2	74.2	32.1	12.7	36
Mean	133	121	112.3	175	145	161	164	106	137

Table 6. Phenotypic correlation coefficients among the different Arabica coffee growth parameters.

Parameter	CLY	TPH	SGR	NPB	IN	CD
CLY	1	0.15**	0.59**	-0.13**	0.31**	0.57**
TPH		1	0.36**	0.36**	0.58**	0.44**
SGR			1	-0.12*	0.39**	0.73**
NPB				1	-0.32**	-0.21**
IN					1	0.56**
CD						1

CLY = Clean yield, TPH = total plant height, SGR= stem girth, NPB = number of primary branches, IN = internode length, CD = canopy diameter.

varieties using individual season's mean as independent variable by the Eberhart and Russel stability model (which is suitable for annual crops) is invalid and leads to wrong conclusions and refinements are required or an appropriate model has to be devised by statisticians for perennial crops (coffee Arabica) to calculate stability of varieties performance across different environments.

Growth characters

Differences among genotypes for plant heights stem girths and canopy diameters were highly significant at all locations. However, means are indicated in Figures 1, 2 and 3. These three growth characters were favored at the mid altitudes where the temperature was high (Table 1). Similar result was reported by Mesfin and Bayeta (1987). But the stunted growth at Jimma as shown in the figures was attributed to poor edaphic factors. Generally, from the growth characters considered, canopy diameter (0.57**) and stem girth (0.59**) exhibited strong positive correlation with yield (Table 6) indicating that these characters have strong tie to improve productivity per tree basis.

Conclusion

Even though genotypes exhibit significant interaction in performance across wide environments, there are special genotypes which exhibited stable performance across such environments. This shows that it is possible to maximize coffee production across the target coffee growing environments in Ethiopia by subdividing the whole environments into sub-regions and developing independent varieties for each sub-region separately.

From the evaluation of genotypes across different environments it was seen that fluctuation of yield of Arabica coffee over seasons was higher at less favorable than favorable environments. However, such fluctuation

of yield can be minimized by applying agronomic practices such as adequate fertilization, mulching or growing coffee orchards in optimum shade levels.

Generally, genotypes of all branch configuration (compact, intermediate or open) exhibited superior fruit production and vegetative growth at medium than high altitude areas showing the fact that the former is more favorable and productive for coffee production than the latter if other climatic and edaphic factors are kept not limiting.

Pre-selection of genotypes at favorable environment favored those genotypes which responded favorably at similar than different environments. Therefore, preliminary evaluations before multi-location adaptation tests should be done in contrasting environments of one favorable and the other unfavorable so that genotypes with better performance in both environments can be fit to be used across wide environments.

Conflict of Interest

The author(s) have not declared any conflict of interest.

REFERENCES

Agwanda CD, Baradat PC, Charrier A, (1997). Genotype by Environment Interaction and its Implication. In: Xvlle Colloque Scintifique International due café Nairobi (Kenya). 7:20-25.

Ariyo OJ (1998). Use of additive main effects and multiplicative interaction model to analyses multi-location varietal trial. J. Genet. Breed. 53:129-134.

Basford KE, Cooper M (1998). Genotype x environment interactions for wheat breeding in Australia. Aus. J. Agric. Res. 49:153-174. http://dx.doi.org/10.1071/A97035

Cooper M, Hammer GL (1996). Synthesis of strategies for crop improvement. In: Plant adaptation and crop Improvement. (Eds M. Cooper and GL Hammer.) pp. 591-623. (CAB. International: Wallingford, UK.) PMid:9239671.

Bayetta B, Behailu A, Fikadu T, Ashenafi A, Tadesse B (2008). Genetic diversity and hetrosis in Arabica coffee. In the proceedings of Coffee diversity and Knowledge Workshop EIAR, Addis Ababa, pp. 50-57.

Behailu W, Abrar S, Nigussie M, Solomon E (2008). Coffee processing and quality research in Ethiopia. In the Proceedings of Coffee Diversity and Knowledge Workshop EIAR, Addis Ababa, pp. 345-356.

Crossa J (1990). Statistical analysis of multi- location trials. Adv. Agron. 44:55-85. http://dx.doi.org/10.1016/S0065-2113(08)60818-4

Eshetu D, Teame G, Girma A (1999). Significance of Minor disease of Coffea arabica Ethiopia: A review. In the Proceedings of the Workshop on Control of Coffee Berry Disease (CBD) in Ethiopia. pp. 58-65.

Jefuka C, Adugna G, Teferi D, Zeru A, Bogale S, Adem A (2012). Development and Release of Coffee Berry Disease Resistant Varieties to Specialty Coffee Producing Regions in Ethiopia. In the Proceedings of the 24th International Conference on Coffee Science San José (Costa Rica), 12th -16th November 2012.

Mesfin K, Bayetta B, Seyoum S (2007). Diversity in the south Ethiopian coffee. 21st Int. Sci. Colloq. On coffee. ASIC, Montpellier, France Mesfin A, Bayetta B (1987). Genotype- environment interaction in coffee, Coffea arabica L. (submitted to EJAS for publication)

Montagnon C, Cilaschristianleory A, Yapo A, Charmentant P (2000). Genotype-locationinteraction for coffee canephora yield in Ivory Coast. Agronomic 20:101-109. http://dx.doi.org/10.1051/agro:2000110

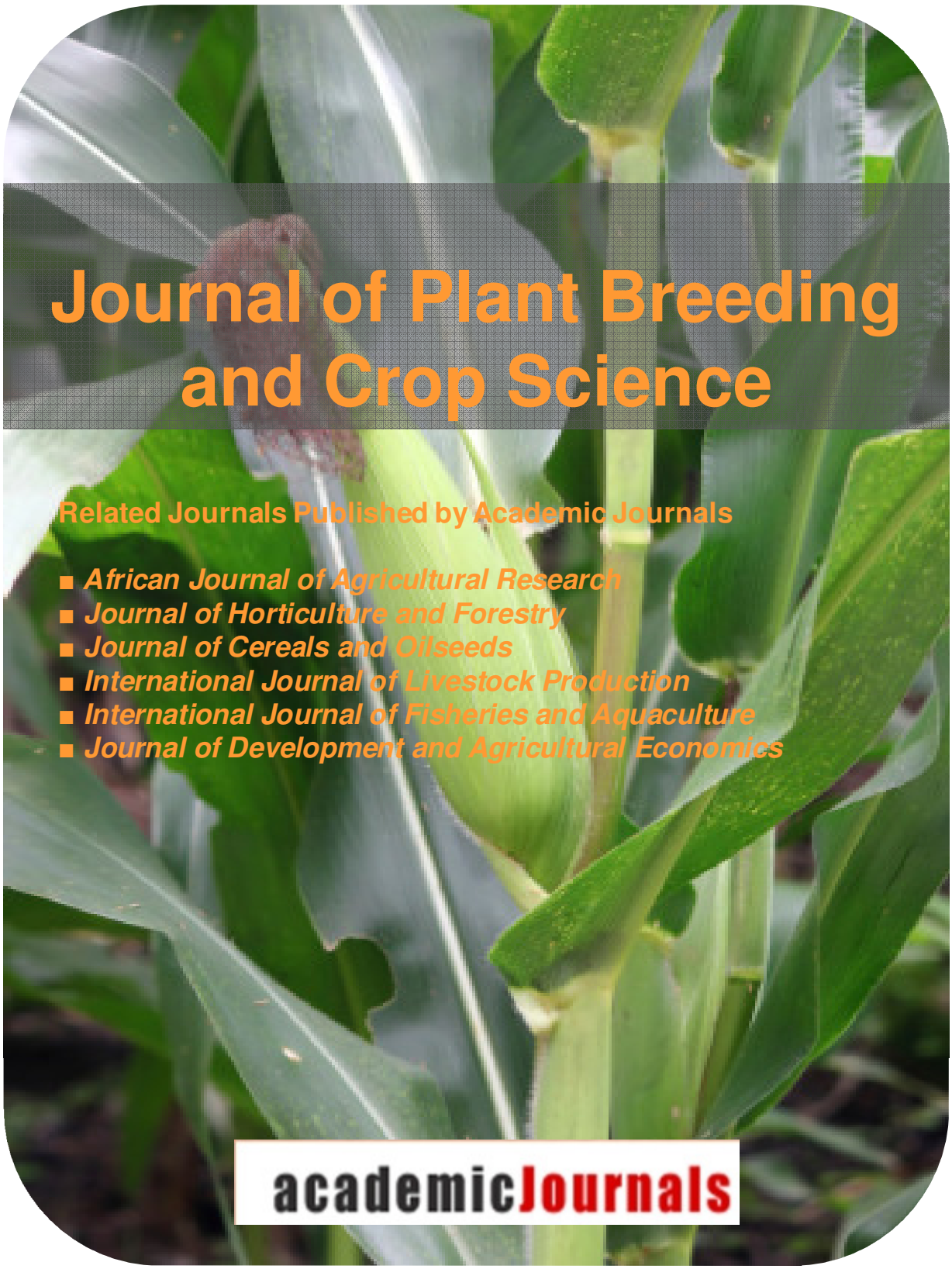
Nigussie E, Deresse T, Berhanu M, Getachew W (2008). Research Center Based Extension Intervention on Improved Coffee Technologies. In the Proceedings of Coffee Diversity and Knowledge Workshop EIAR, Addis Ababa, pp. 345-356.

Yonas B, Bayetta B (2008). Cultivar by environment interaction and stability analysis of Arabica genotypes. In the Proceedings of Coffee Diversity and Knowledge Workshop EIAR, Addis Ababa. pp. 58-63.

Yonas B (2014). Assessments of resistances of Indigenous Arabica Coffee Genotypes for Multiple Diseases. Greener journal of plant breeding and crop science. 2(3):054-061.

Workafes W, Kassu K (1999). Coffee production system in Ethiopia. In the Proceedings of Coffee Diversity and Knowledge Workshop EIAR, Addis Ababa, pp. 99-106.

Wrigley G (1988). Coffee. Longman Scientific and Technical. England. P. 639.



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