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Participatory selection of a maize (*Zea mays* L.) variety for the control of stem borers in a southeastern Nigeria location

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Abstract

Participatory varietal selection is premised on the basis that only a small percentage of varieties developed by breeders are eventually utilized because farmers are left out of the selection process. Consequently a total of 275 farmers were engaged in the promotion of stem borer resistant maize varieties in the stem borer endemic maize growing ecologies of southeastern Nigeria over a three-year period. Results obtained revealed the superiority of the two tested stem borer resistant varieties over the local check with one of them, Ama-TZBR-W, being more preferred by farmers. The preferred variety had better overall appeal, increased number of ears harvested and almost a four-fold increase in the number of marketable cobs when compared with the local check under the predominantly intercropping pattern practiced in the region, especially in the late cropping season, a season with high incidence of borer infestation. Furthermore, cost-benefit analysis of the introduced technology showed a return of N35 for every Naira invested by the farmer on cultivation of resistant maize variety in the study area. Nonetheless, an acceptable maize variety for cultivation in the area should in addition to having borer resistance to ensure yield stability, must also have well filled cobs and good storability, two essential attributes for food security.

Key words: *Zea mays* L., stem borer infestation, resistant variety, participatory selection, pairwise comparison.

Introduction

Maize (*Zea mays* L.) production in southeastern Nigeria is constrained mainly by stem borer attacks. Damage done to the maize crop include poor stand establishment and growth, dead heart in young plants, lodging in older plants and reduced grain yield [6, 9]. Several studies [17, 21, 22] have shown that grain yield losses due to borer infestation could be as high as 46% in high yield environments or 58% in lower yield environments even when chemicals are used for protection. Although intercropping maize or sorghum crop with non-host crops such as cassava or cowpea is known to control stem borers [3, 4, 18 19], the use of resistant varieties offers a more sustainable solution for controlling the pest, especially when used in combination with other complementary crop management options including intercropping [24]. Maize improvement efforts at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, have resulted in the development of varieties with resistance to stem borers that have been tested on-farm in the region. Thus, the use of such maize varieties alone or in combination with other complementary crop management practices, relevant to the area, may open up new possibilities for increasing maize production and utilization in stem borer endemic ecologies of Nigeria.

Several workers [15, 25, 26, 30] have highlighted approaches that can be used to identify cultivars that are acceptable to resource-limited farmers. Prominent among these is participatory varietal selection that attempts to exploit variation found in released varieties or in genotypes that are at advanced stages of testing by testing them jointly with farmers [32]. This approach that help farmers to overcome constraints that cause them to grow landraces or obsolete varieties[31] has been used with success in many countries to identify crop cultivars suitable for resource-poor farmers [10, 14-16, 20, 29, 32]. Witcombe *et al.* [30] have highlighted four phases that enhance cultivar adoption by farmers as (i) identification of farmers' needs in a cultivar, (ii) determination of suitable genotypes to test with farmers, (iii) experimentation on the acceptability of the identified varieties in farmer's fields and (iv) dissemination of the farmer-preferred cultivar(s). We have therefore used this approach together with community-based seed production system to promote an integrated maize stem borer management technology among small-holder farmers in the forest region of southeast Nigeria.

Materials and Methods

Early season planting: Two independent group discussions, one each at the beginning of the early and late seasons, were held with farmers in 2001 to elicit farmers' responses on preferred maize characteristics and varieties. Consequently, a total of 205 field demonstration trials comparing stem borer resistant maize with a local check, were conducted with farmers in Abia State of Nigeria during the early cropping season of 2001. Of the trials, 175 had one of two stem borer resistant varieties, namely TZBR Eldana 3

and Ama TZBR-W, compared with a local check while the remaining 30 trials had the two resistant varieties being compared with a local check. The resistant varieties were obtained from IITA and the trials were conducted immediately after the first group meeting. Abia State is one of the nine states in Nigeria designated as a forest benchmark area for the Ecoregional Programme for Humid Tropical Africa (EPHTA) with stem borers as one of the major constraints to maize production.

Each trial was managed by the farmer with guidance from the technical staff. Thirty of the trials had the two resistant varieties being compared to the local check while the remaining had only either of the two resistant varieties being compared with the local variety. The plot sizes for each entry was 10 m x 10 m, therefore, total land area for each trial was from 200 m to 300 m depending on whether one or both resistant varieties were used. Each entry was planted at an intra row spacing of 50 cm on 75 cm wide ridges. Three seeds were planted per hill but later thinned to two plants at three weeks after planting (WAP) to give a plant population of 55,300 plants/ha. The fields were hoe-weeded at three and six weeks after planting (WAP) followed by hand removal of other annual weeds as required. NPK fertilizer was applied as practiced in the particular location.

Late season plantings: At the conclusion of the early season trials, farmers rated Ama TZBR-W ahead of TZBR Eldana 3, which they considered less tasty. Therefore, using Ama TZBR-W and other local varieties that had the preferred taste, the eight characteristics initially itemized by farmers in the early season were reduced to five and used to rank varieties in the late season. Forty trials were then conducted in the late season of 2001 by substituting Ama TZBR-W in the intercropped farming system of the area and comparing this with the existing farmers' practice of using local maize variety as the control. A third treatment of planting four rows of cassava followed by four rows of the improved maize, to enable the relay planting of maize into the same land the following season (strip-relay intercropping), was included to aid better utilization of land. Plot size for each trial was 20 m x 20 m with spacing and other agronomic practices carried out as earlier described for the early season trials, but cassava was planted on ridges spaced 75 cm apart but with intra-row spacing of 1 m. Feedback obtained from the late season trials of 2001 suggested preference for maize/cassava intercrop as opposed to the strip relay because of its perceived better land utilization. Consequently, 50 and 20 field trials were conducted in the late seasons of 2005 and 2006 respectively by comparing Ama TZBR W and local variety in the intercropped system using plot size of 20 m x 20 m for each trial.

Data collection: Data collected from the early season trial of 2001 included number of plants with leaf damaged at 4 and 8 WAP, number of plants with broken stems at 4 and 15 WAP and number of ears harvested. Because 'green maize' sold as maize on the cob command better price, data were collected on the number of marketable cobs, separated into big and small cob sizes since each is priced differently. Where the crops were allowed to dry, grain yield was estimated by adjusting cob yield to 80% shelling weight. For the late season trials, data were also collected prior to harvesting on stem borer damage (%) while resistance to stem borer was scored on a scale of 5 = resistant (no sign of infection) to 1 = highly susceptible.

Additional data were collected from the 30 trials that had the two resistant varieties being compared with the local check by rating for plant, ear and cob aspects on a scale of 1 (poor) to 5 (excellent) and variety acceptability also on a scale of 1 (least preferred) to 5 (most preferred) for the same parameters. Farmers also ranked the two technologies being compared with the farmers' practice in the late season of 2001 for performance, yield and land utilization on the same scale. However, ratings for crop performance traits namely; crop vigour, plant and ear aspects for the late season trials of 2005 and 2006 were done on a scale of 1 = excellent to 5 = very poor as desired by the farmers.

Data analyses: In the early season of 2001, data from all farms that had at least one resistant variety being compared with a local variety were pooled to compare the yield of resistant with local only without regard to variety per se. Furthermore, data collected from each of the three technologies evaluated in the late season of 2001 and reduced to two in the late seasons of 2005 and 2006 were also pooled and subjected to analyses of variance (ANOVA). Pertinent means from the ANOVA were separated by the use of Least Significant Difference (LSD) or Duncan Multiple range Test[27].

Results

Early season plantings: Pairwise comparison of preferred maize characteristics by the farmers is presented in Table 1. Resistance to stem borer was the most important characteristic highlighted from among the eight traits considered important by farmers, followed by storability and grain filling. Plant height, taste and starch content were of least importance. Cob size, an important trait for trade, was rated a distant fifth because it was an assumed character implying that all maize varieties should normally have big cob sizes for acceptance.

Performance of the two improved maize varieties and farmers' checks evaluated in the early season trials is presented in Table 2. The borer resistant maize varieties did not differ for crop damage

Table 1. Pairwise comparison of preferred maize characteristics among farmers in on-farm trials conducted in Abia State of southeastern Nigeria in 2001.

Character	1	2	3	4	5	6	7	8
1. Insect resistance								
2. Storability	1							
3. Plant height	1	2						
4. Grain filling	1	2	4					
5. Ear prolificacy	1	2	5	4				
6. Taste	1	2	6	4	5			
7. Cob size	1	2	7	4	5	7		
8. Starch content	1	2	8	4	5	8	7	
Overall ranking	1	2	8	3	4	7	5	6

parameters but Ama-TZBR-W was better than TZBR Eldana 3 for number of plants with damaged leaves at 8WAP in addition to cob aspect and general acceptability. The two introduced varieties were, however, better than the local at every stage of crop assessment. The borer resistant varieties further had bigger and well-filled cobs and were rated superior to farmers' varieties with respect to plant and ear characteristics and overall acceptability. Ama-TZBR-W had a yield advantage of 39 and 68% while TZBR Eldana 3 had 35 and 65% for big and small cob sizes over farmer's variety, respectively. Nonetheless, the borer resistant varieties were similar for gross plot yield (Table 2). The results of the on-farm trials combined (Table 3) showed that the borer resistant varieties were more preferred for plant ear and cob aspect and also had better acceptability values than the local. Furthermore, they had more marketable cobs and better grain yield than the local regardless of whether they were separated into big or small sizes and also had grain yield advantage of almost 50% over the local. However, Ama-TZBR-W had better overall preference than TZBR Eldana 3 (Table 3).

Late season plantings: Rating of maize varieties on the basis of five most important farmers characteristics, namely stem borer resistance, storability, grain filling, ear prolificacy and big cob size, showed that Ama-TZBR-W was the most preferred in four out of the five cases (Table 4). The popular local maize variety, Bende white, although rated very low for storability and insect resistance, ranked overall second because of its soft endosperm, a preferred trait for roasting purposes.

Performance of the stem borer management technologies in the late season of 2001 is presented in Table 5. Farmers' rating of the technologies revealed that the two introduced technologies involving Ama-TZBR-W intercropped or strip-relayed with cassava were more preferred to the farmer's practice with regards to all parameters used for assessment. However, there was no significant difference in farmers' perception of the introduced technologies as they were both rated equally for all the parameters. Ama-TZBR-W intercropped with cassava or with cassava introduced as relay crop had significantly lower borer damage rating when compared with the farmers check. Intercropping the variety with cassava further gave a yield advantage of almost 50% over the farmer's variety while the strip-relay option further gave an additional yield advantage over both intercropped situation and farmer's variety (Table 5). However, ratings of the two introduced technologies for crop performance, crop yield and land utilization revealed that Ama-TZBR-W intercropped with cassava was more preferred when cassava was introduced as relay crop only on the basis of better land utilization (Table 6).

The results of the 2005 and 2006 late season trials are presented in Table 7. Ama-TZBR-W intercropped with cassava was superior to farmer's practice for crop vigour, plant and ear characteristics and cob yields. Plant aspect, a composite trait that measure overall physical appeal of the crop including borer damage revealed that Ama-TZBR-W was by far superior to the local variety in the two years. Ratings of crop vigour and ear aspect followed a similar trend. The improved performance of the resistant variety was further highlighted by increase in number of cobs harvested and almost a four-fold increase in the number of marketable cobs obtained in each of the two years relative to the local check (Table 7).

Table 2. Stem borer damage rating and grain yield of two resistant and a local maize variety evaluated in 30 demonstration plots in the early season of 2001 in Abia State of Nigeria.

	Crop damage parameters						
	No. of plants with leaf damaged		No. of plants with broken stems		Grain yield (kg/ha)		
Variety	4WAP	8WAP	4WAP	15WAP	Big cob	Small cob	Total yield
Ama-TZBR-W	8	15	10	27	1312	1232	2544
TZBR Eldana 3	15	25	8	25	1232	1144	2376
Farmer's variety	29	35	22	37	1160	392	1552
LSD α 0.05	8.73	8.16	6.18	5.25	64	376	432

Table 3. Plant, ear and yield characteristics of stem borer resistant maize varieties and a local check evaluated in farmers fields of Abia State in south eastern Nigeria in the early season of 2001.

Variety	Plant aspect	Ear aspect	Cob aspect	Acceptability	Variety	Ear No.	Big cobs	Small cobs	Grain yield (kg/ha)
Ama-TZBR-W	4.65	4.30	4.40	4.55	Resistant variety*	68.63	48.67	24.40	1968
TZBR Eldana 3	4.15	3.65	3.80	4.00					
Farmer's variety	2.90	2.65	2.85	2.60	Farmers' variety	52.63	28.22	19.96	1272
LSD α 0.05	0.57	0.46	0.50	0.36		4.03	2.67	4.01	504

Table 4. Ranking of maize varieties in Abia State of Nigeria based on five most important characteristics highlighted by farmers in the late season of 2001.

Character	Bende White	Okaranmanu	Obaduike	Ama-TZBR-W
Insect resistance	0	3	3	5
Storability	0	3	3	5
Grain filling	5	5	5	5
Prolificacy	2	4	0	5
Cob size	7	3	2	3
Overall ranking	2	4	3	1

Table 5. Plant, ear and yield characteristics of stem borer resistant maize and a local check evaluated in 40 farmers fields of Abia State in south eastern Nigeria in the late season of 2001.

Technology	Plant aspect	Ear aspect	Cob aspect	Stem borer rating	Overall preference	Damage %	Rating	Big cob	Small cob	Cumulative cob yield
Ama-TZBR-W C1 + Cassava (intercrop)	4.45	4.20	4.40	4.30	4.45	34.45	2.48	31.30	10.61	41.91
Ama-TZBR-W C1 + Cassava (Relay)	4.35	4.50	4.45	4.30	4.20	38.70	2.61	35.78	12.52	48.30
Local variety + Cassava (intercrop)	2.80	2.50	2.75	2.10	1.60	69.09	4.04	17.00	6.35	23.35
LSD α 0.05	0.36	0.35	0.43	0.40	0.38	7.79	0.40	4.35	3.10	6.28

Table 6. Farmers' criteria for preference of maize stem borer management technology evaluated with 40 farmers in the late season of 2001 in southeast Nigeria.

Criteria	Ama-TZBR-W C1 + Cassava (intercrop)	Ama-TZBR-W C1 + Cassava (Relay)
Crop performance*	3.35	3.41
Crop yield	4.25	4.45
Land utilization	3.35	3.10
LSD (0.05)	0.36	0.34

*, Assessment based on crop vigour and borer infestation rated on 5 = very good to 1 = not desirable.

Table 7. Crop vigour, plant and ear characteristics of stem borer management technologies evaluated in the late seasons of 2005 and 2006 in southeast Nigeria.

	2005 late cropping season (n = 50)					2006 late cropping season (n = 20)				
Technology	Crop vigour	Plant aspect	Ear aspect	Ear No.	Marketable cobs/plot	Crop vigour	Plant aspect	Ear aspect	Ear No.	Marketable cobs/plot
Ama TZBR-W + Cassava	1.29	1.86	1.64	205	174	1.3	2.0	2.3	227	192
Local maize + cassava	4.07	4.07	4.21	131	42	3.2	4.3	4.5	77	47
F –Test	**	**	**	**	**	**	**	**	**	**
SED	0.61	0.59	0.71	28.62	12.63	0.30	0.41	0.42	21.52	20.87

**; Significant at 0.01 level of probability.

Discussion

Socio-economic surveys are important to understanding farmers' practice and beliefs because farmers are usually not a homogenous group [1]. Due to population pressure and farming systems, land for arable crop farming in the agro-ecologies of southeastern Nigeria is usually a constraint, especially in the late season. This is because intercropping of tuber crops (cassava or yam) that normally last for a whole year with maize/melon/telfaria as a main feature of their farming system often tie down lands cropped in the early season, thereby making such land unavailable for maize cultivation in the late season. This is exemplified by the average farm size of less than one hectare per farm household. This situation, as earlier noted in Malawi [8, 24], often place majority of rural farm households at the margin of subsistence as typified by most farming communities in southeast Nigeria.

Understanding farmers' perception and priorities is crucial to facilitating adoption of any technology [7, 25]. Although cob yield is usually considered a priority trait to maximizing yield, it ranked a distant fifth when compared with traits that confer yield stability and food security, namely insect resistance and storability, that were ranked first and second respectively by the farmers. As noted by Snapp and Slim [23], while researchers may monitor returns by measuring crop yields per land area, farmers assess a range of other traits which often make their perceptions of returns quite different from those of researchers. Such traits of interest to farmers include organoleptic properties of the varieties [2], adaptation to local conditions, yield security, cash returns, grain quality traits, low labour requirements and tolerance to abiotic and biotic stresses [11, 25]. Thus, involving farmers early in the process of variety selection, as was demonstrated in this study, will enhance early adoption of desirable technologies. Within the three-year study period, the target of promoting the adoption of maize stem borer resistant technologies in an endemic area and using the participatory selection approach was achieved. Cost-benefit analysis of the introduced technology (data not shown) showed a return of N35 for every Naira invested by the farmer on cultivation of resistant maize variety in the study area. Reports of such participatory selection successes abound in the literature [10, 12, 14, 29].

Dogbe *et al.* [10] noted that the success of a participatory varietal selection process is highly related to the availability of adequate quantity of back-up seeds. Although seeds of the improved maize varieties were adequate throughout the duration of the study, the project facilitated the formation of community based seed production scheme by partnering with a local NGO to empower farmers on techniques of maize seed production to forestall reliance on grains as seeds. Follow-up visits to the sites has confirmed the effectiveness of the scheme.

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References

[1]Ahmed, M.M., Rohrbach, D.D., Gono, L.T., Mazhangara, E.P., Magician, L., Masendeke, D.D. and Alibaba, S. 1997. Soil fertility management in communal areas of Zimbabwe: Current practices, constraints and opportunities for change. Results of a diagnostic survey. Southern Eastern Africa Region working paper No. 6. International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Bulawayo, Zimbabwe.

[2]Alika, J.E. and Okwechime, C.C. 1990. Palatability tests of seventeen maize (*Zea mays* L.) genotypes for human consumption. Journal of Agric. Sci. **114**:157-159.

[3]Adetiloye, P.O., Oyekanmi, A.A. and Olatunde, G.O. 2002. Evaluation of four cropping systems in the control of maize stem borers and the effects on maize growth and grain yield. ASS Series A **2**(1):55-61.

[4]Ampong-Nyarko, K., Seshu, K.V., Reddy, R.A. and Saxena, K.N. 1993. Mechanisms of low insect pest incidence in intercropping: *Chilo partellus* oviposition on non-host cowpea. In Odindo, M. (ed.) Beneficial African Insects: A Renewable Natural Resource. Proceedings of the 10th Meeting of the African Association of Insect Scientists, 5-10 September, 1993. Mombassa, Kenya, pp. 103-108.

[5]Ampong-Nyarko, K., Reddy, K.V., Nyang'or, R.A. and Saxena, K.N. 1994. Reduction of pest attack on sorghum and cowpea by intercropping. Entomologia Experimentalis et Applicata **4**:49-46.

[6]Bowden, J. 1976. Stem borer ecology and strategy for control. Annals of Applied Biology **84**(1):107-111.

[7]Chambers, R and Ghildyal, B.P 1985. Agricultural research for resource-poor farmers. The farmer-first-and –last model. Agricul. Admin. **20**:1-30.

[8]Cromwell, E. and Winpenny, J. 1993. Does economic reform harm the environment? A review of structural adjustment in Malawi. J. Int. Dev. **5**:623-649.

[9]Dabrowski, Z.T., Everett, L., Mareck, J.H. and Nwosu, K. 1983. Stem borer resistance screening. International Institute of Tropical Agriculture (IITA) Annual Report, pp. 39-41.

[10]Dogbe, W., Bam, R., Craufurd, P.Q., Marfo, K., Dorward, P., Opoku-Apraku, A., Bimpong, I., Djagbety, D., Gyasi, K. and Asiedu, E. 2002. The role of participatory crop improvement for upland rice in Ghana. In Witcombe, J.R., Parr, L.B. and Atlin, G.N. (eds). Breeding Rainfed Rice for Drought-Prone Environments: Integrating Conventional and Participatory Plant Breeding in South and Southeast Asia. Proceedings of a DFID Plant Sciences Research Programme/IRRI Conference, 12-15 March, 2002. IRRI, Los Banos, Laguna, Philippines.

[11]Fischler, M, David, S., Farley, C., Ugen, M. and Wortmann, C. 1996. Applying farmer participatory research methods to planning agricultural research: Experience from Eastern Africa. J. Farm Syst. Research-Extension **6**:37-54.

[12]Goyal, S.N., Joshi, A. and Witcombe, J.R. 2000. Participatory crop improvement in maize in Gujarat, India. In Proc. Int. Symp.on Participatory Plant Breeding and Participatory Plant Genetic Resource Enhancement: An Exchange of Experience from South and South East Asia, Pokhara, Nepal 1-5 May 2000. CGIAR System wide Programme on Participatory Research and Gender Analysis for Technology Development and Institutional Innovation.

[13]Huan, H., Thiet, L.V., Chien, H.V. and Heong, K.L. 2005. Farmers' participatory evaluation of reducing pesticides, fertilizers and seed rates in rice farming in the Mekong Delta, Vietnam. Crop Protection **24**:457-464.

[14]Joshi, A. and Witcombe, J. R. 1995. Farmer participatory research for the selection of rainfed rice cultivars. In Proceedings of the International Rice Research Conference, 13-17 Feb. 1995. Fragile Lives in Fragile Ecosystems, IRRI, pp. 825-842.

[15]Joshi, A. and Witcombe, J.R. 1996. Farmer participatory crop improvement. II. Farmer participatory variety selection, a case study in India. Experimental Agriculture **32**:461-477.

[16]Joshi, A. and Witcombe, J. R. 1998. Farmer participatory approaches for varietal improvement. In Witcombe, J.R., Virk, D.S. and Farrington, J. (eds). Seeds of Choice. Making the Most of New Varieties For Small Farmers. CAZS and ODI by Oxford IBH, New Delhi and Intermediate Technology Publications, London, pp. 172-190.

[17]Konak, C. 1988. Planting of maize at different times to reduce borer damage in Aegean Region. Proc. of a Symposium on Corn Borers and Control Measures. National Maize Research Program and CIMMYT, 1-3 Nov. 1988, Adana, Turkey, pp. 21-24.

[18]Lawani, S.M. 1982. A review of the effects of various agronomic practices on cereal stem borer population. Tropical Pest Management **28**(30):266-276.

[19]Maluleke, M.H., Addo-Bediako, A. and Knigsley, K.A. 2005 Influence of maize-lablab intercropping on the Lepidopterous stem borer infestation in maize. Journal of Economic Entomology **98**:384-388.

[20]Maurya, D.M., Bottral, A. and Farrrington, J. 1988. Improved livelihoods, genetic diversity and farmers' participation: a strategy for rice breeding in rainfed areas of India. Expt. Agric. **24**:311-320.

[21]Mihm, J.A. 1994. Maize pest management - Multiple insect and disease resistant varieties are the key to success. In Jewell, D.C., Waddington, S. R., Ransom, J. K. and Pixley, K. V. (eds). Maize Research for Stress Environments. Proc. of 4th Eastern and Southern Africa Regional Maize Conf. Harare, Zimbabwe 28th March -1st April, 1994, pp. 176-181.

[22]Simsek, N., Gllu, M. and Zeren, O. 1988. Studies on the effectiveness of some agrochemicals against stem borers, *Seasmia nonagriodes* Lef., *Seasmia cretica* Led. and European corn borer *Ostrinica nubilalis* Hbn. in the Mediterranean Region of Turkey. Proc. of a Symposium on Corn Borers and Control Measures. National Maize Research Program and CIMMYT, 1-3 Nov. 1988. Adana, Turkey, pp. 44-54.

[23]Snapp, S.S. and Silim, S.N. 2000. Farmer preferences and legume intensification for low nutrient environments. Plant and Soil **245**:181–192.

[24]Snapp, S.S., Rohrbach, D.D., Simtowe, F. and Freeman, H.A. 2002. Sustainable soil management options for Malawi: Can smallholder farmers grow more legumes? Agriculture, Ecosystems and Environment **91**(1-3):159-174.

[25]Sperling, L., Loevinsohn, M.E. and Ntabomvura, B. 1993. Rethinking the farmer's role in plant breeding: Local bean experts and on-station selection in Rwanda. Expt. Agric. **29**:509-519.

[26]Sthapit, B.R., Joshi, K.D. and Witcombe, J.R. 1996. Farmer participatory crop improvement. III. Participatory plant breeding. A case study for rice in Nepal. Expt. Agric. **32**:479-496.

[27]Steel, R.G.D. and Torrie, J.H. 1980. Principles and Procedures of Statistics. A Biometrical Approach. 2nd edn. Mc Graw Hill Book Inc., New York, 580 pp.

[28]Willey, R.W., Mohammed, N. and Morse, S. 1997. Factors affecting compensation in intercropping when one component fails. Trop. Agric. **74**:313-316.

[29]Witcombe, J.R. and Virk, D.S. 1999. The success of participatory varietal selection in a high potential production system in India. How important is the participation? Ashby, J.A. and Sperling, L. (eds). Participatory Plant Breeding and Rural Development. PGRA, Cali, Columbia.

[30]Witcombe, J.R., Joshi A., Joshi, K.D. and Sthapit, B.R. 1996. Farmer participatory crop improvement. I. Varietal selection and breeding methods and their impact on biodiversity. Expt. Agric. **32**:445-460.

[31]Witcombe, J.R., Peter, R., Jones, S. and Joshi, A. 1999. Farmer participatory crop improvement: IV. The spread and impact of a rice variety identified by participatory varietal selection. Expt. Agric. **35**:471-487.

[32]Witcombe, J.R., Joshi, A. and Goyal, S.N. 2003. Participatory plant breeding in maize: A case study from Gujarat, India. Euphytica **130**:413-422.