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Improving Yield, Profitability and Water Productivity of Crops in Arid Fringes through Farmers Participatory Action Research

S.P.S. Tanwar*, Shiv Datt[1], S.S. Rao[2] and P.L. Regar

ICAR-Central Arid Zone Research Institute, Regional Research Station, Pali-Marwar 306 401, India

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Abstract: Arid fringes have a comparative advantage of higher rainfall than the core desert leading to diverse micro-farming situations. Hence tailoring the technologies to local situations is required for their fast dissemination. Thirty eight farmers' participatory trials were conducted in four representative villages of Pali district, Rajasthan. Crop wise constraints were identified of which the most conspicuous were the lack of short duration varieties and improper nutrient application. In mung bean, the response of fertilizers was 5-16%. But the combined effect of varieties and fertilizers was 16-148%. Clusterbean variety RGC 936 yielded 79% higher over local and 25% over RGC 1003. Dual purpose sorghum (CSV 15) + fertilizers increased dry fodder yield by 1.75-2.75 times over farmers' practice and in grain purpose sorghum (CSV 17) yield improved by 140%. Sesame variety RT 127 increased the yields between 62-68%. Amongst the salinity tolerant mustard varieties GM 3 and CS 54, the former produced 22.4% higher grain yield over the latter variety and 33% over established variety Bio 902. Farmers' preferred wheat variety Raj 4037 for its chapatti making quality gave additional yields of 20-30%. Improvement in yields was ultimately reflected in improved water productivity. The water productivity in different kharif crops varied between 0.085-0.417 kg grain m^{-3} due to improved practices. In the irrigated rabi crops i.e. wheat and mustard, the water productivity ranged between 0.80-0.60 and 0.228-0.279 kg grain m^{-3}, respectively. The impact of technologies was clearly visible even after two years of their withdrawal.

Key words: Farmers' participatory research, arid fringes, nutrient management, improved varieties.

Since deserts have no discrete boundaries, a large transitional belt exists having characteristics of both arid and semi-arid regions and representing an array of micro-farming situations. Transitional zone of Luni basin located in Pali and Jalore districts of Rajasthan typically represents fringes of the Great Indian Thar desert. Since these regions receive comparatively higher rainfall (400-600 mm) than the core area of arid zone, total area under cultivation is high (54%) of which 16% is irrigated (Kar, 2014). Soils are shallow and quality of irrigation water is poor so single cropping is a norm. Major crops of the region are sorghum, mung bean, sesame and clusterbean in kharif season and wheat and mustard in rabi season. Water has been the scarcest resource, thus, more crop and income per drop of water is the ultimate target. Out of the eight lakh ha crop lands in Pali district only 1.2 lakh ha area is irrigated. Soils of the region are poor in fertility. Further, the application of nutrients to the crops is nominal mainly due to low response of existing non-descript land races and aberrant weather conditions. Thus, to improve the water productivity there is need to identify location specific cultivars and improved nutrient management strategy for them (Rao *et al.*, 2004; Venkateswarlu and Aggarwal, 1991). For faster dissemination of technologies, assessing the needs of farmers and tailoring the solutions according to the micro farming situation is the need of hour. Several cases where technical options were successfully generated and adopted by involving farmers in the research process have been demonstrated (Versteeg and Koudokpon, 1993; Poudel *et al.*, 2000; Harris *et al.*, 2001; Dorward *et al.*, 2007; Tanwar *et al.*, 2012). The farmer evaluation study is a way of identifying and characterizing different criteria that farmers would want to use in choosing from among the varieties of different crops. An attempt has been made to identify the problems and solutions thereof in

*E-mail: spstanwar@gmail.com

Present address: [1] KAB-II, ICAR, New Delhi; [2] RRS, NBSS&LUP, Udaipur, Rajasthan

the existing cropping systems of this region *via* participatory mode under the aegis of Farmers Participatory Action Research Project in three Panchayat Samities of the Pali district.

Materials and Methods

A farmers' participatory action oriented research program was carried out in four representative villages from three Panchayat Samities of Pali district of Rajasthan i.e. Bhadarlao and Busi (tehsil Rani), Siyat (tehsil Sojat) and Dhamli (tehsil Kharchi). The soil of the villages were shallow loam to clay loam with pH ranging from 7.2 to 8.5, low in organic carbon and medium to high in phosphorus and potash (Table 1). Severe drought was experienced during 2009 with the rainfall of only 153 mm, however, 2010 was a normal year with annual rainfall of 415 mm. Participatory rural appraisal (PRA) was carried out through focused group discussions with all the stakeholders i.e. farmers, state agriculture supervisors, seed and fertilizer suppliers and common village meetings. Accordingly, the trials were framed out and managed by the farmers themselves. There were 38 trials conducted from 2008-10. During kharif the treatments consisted of improved and local varieties of mung bean (RMG 62, GM 4, SML 668 and local) with nutrient management, clusterbean (RGC 936, RGC 1003, RGM 112 and local), sorghum (CSV 15, CSV 17 and local) with nutrient management and sesame (RT 127 and local). During rabi, wheat (Raj 4037 and Raj 3077) and mustard (GM 3, CS 54 and Bio 902) were included in the trials. Farmers led all the major aspects of the evaluation which were followed in the study. Frequent visits were made to the sites and farmers' meets were organized. After first year of experimentation itself availability of improved seeds was assured through government agencies and local seed stores. Post assessment was also carried out after two years of withdrawal. Water productivity (WP) was worked out by dividing the grain yield by the water applied and/or received during the crop growing season.

Table 1. Soil characteristics of villages under study

Soil Depth	Shallow (30-45 cm)			
Texture	Sandy loam			
Bulk density	1.36-1.49 g cm^{-3}			
Field capacity	17.2%			
Wilting point	7.1%			
pH	7.2-8.5			
EC	2.1 -6.7 dS m^{-1} (Av. 3.8)			
	Bhadarlao	Siyat	Dhamli	Busi
O.C. (%)	0.31	0.21	0 .24	0.21
P_2O_5 (kg ha^{-1})	36.0	37.0	18.0	28.0
K_2O (kg ha^{-1})	365	325	445	295

Results and Discussion

Participatory rural appraisal (PRA)

In the stakeholders meetings, crop wise constraints were identified (Table 2). It was found that farmers do not apply fertilizers to the leguminous crops of kharif season at all and apply sub- optimal doses to sorghum. Farmers perceived lack of availability of good varieties as single most important constraint in increasing productivity of all the crops.

Table 2. Crop wise constraints identified through PRA in operational villages.

Crop	Constraints/requirement
Sorghum	Dual purpose variety needed, less or no fertilizer application at all
Mung bean	Prevalent local seeding material, lacks synchronous maturity, poor nutrient management
Clusterbean	Early maturing variety needed, no fertilizer application
Sesame	Early maturing variety needed, no fertilizer application
Wheat	Poor grain quality of existing variety, terminal heat stress, and suitable variety for salt affected areas is needed.
Mustard	Improved variety for salt affected soils needed

Crop productivity and economics

Mung bean: Single intervention of applying fertilizers @ 10 kg N + 40 kg P_2O_5 ha^{-1} to local variety of mung bean increased its yield between 5% in Busi village to 33% in Siyat village. However, when applied along with improved mung bean varieties, the yields increased by 16-148% at different locations (Table 3). Maximum yield of 533 kg ha^{-1} was recorded under RMG 62 followed by GM 4 in Busi village. By adopting improved practices i.e. improved varieties and adequate fertilizers, additional income enhanced by Rs. 2010 to 14970 ha^{-1}.

Table 3. Response of mung bean to scientific interventions on farmer's field

Village	Treatments	Grain yield (kg ha^{-1})	% increase over farmers' practice	WP (kg m^{-3})	Gross returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
Bhadarlao (2)*	Farmers' practice (Local variety + No fertilizers)	140		0.056	8400	6550	1850	1.28
	Local variety + fertilizers**	162	16	0.069	9720	7240	2480	1.34
	RMG 62+ fertilizers	215	53	0.086	12900	7400	5500	1.74
Busi (3)	Farmers' practice (Local variety + No fertilizers)	280		0.078	16800	6800	9310	2.24
	Local variety + fertilizers	293	5	0.081	17580	7490	10780	2.58
	RMG 62+ fertilizers	533	148	0.147	31980	7700	24280	4.15
	GM4 + fertilizers	390	117	0.108	23400	7700	15700	3.03
Siyat (2)	Farmers' practice (Local variety + No fertilizers)	135		0.075	8100	6550	1550	1.24
	Local variety + fertilizers	180	33	0.118	10800	7240	3560	1.49
	SML 668 + fertilizers	250	85	0.185	13800	7400	6400	1.86

*Figures in parenthesis represents number of trials conducted, **Fertilizer dose: 10 kg N and 40 kg P_2O_5 ha^{-1}.

Clusterbean: Varieties RGC936 and RGC 1003 were evaluated against un-descript farmers' variety (Table 4). At Busi village RGC 936 yielded 79% higher over local and 25% over RGC 1003. Since there was a severe drought during crop season (2009), except for improved varieties in Busi village, farmers incurred net loss in clusterbean cultivation.

Sorghum: Both dual (CSV 15) and grain purpose (CSV 17) varieties under optimum dose of fertilizers (40 kg N + 20 kg P_2O_5 ha^{-1}) were tested against farmers' practice (local variety + no fertilizer application, Table 5). Dual purpose variety CSV 15 produced 257% higher dry fodder in Bhadarlao (25 q ha^{-1}) and 175% in Siyat (55 q ha^{-1}) villages. However, seeds did not reach to maturity in these villages due to severe drought. As the rainfall was comparatively more in Busi village, seed setting occurred both in local as well as grain purpose variety CSV 17. This variety when grown along with optimum dose of fertilizer produced 140% higher grain, but fodder production was 30% less than the local variety.

Sesame: Similarly, seed replacement in sesame (RT 127) increased the yields between 62-68% (Table 6). This resulted in additional returns of Rs. 6790-7529 ha^{-1} with a B:C ratio of 4.08-3.87.

Wheat: During rabi season, at Baderlao and Damli villages the wheat variety Raj 4037 out

Table 4. Response of clusterbean to improved varieties on farmer's field (2009)

Village	Variety	Grain yield (kg ha^{-1})	% increase over farmers' practice	WP (kg m^{-3})	Gross returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
Bhadarlao (2)	Local	128		0.051	3840	6550	-2710	0.59
	RGC 936	200	56.3	0.080	6000	7400	-1400	0.81
Busi (2)	Local	195		0.078	5850	6500	-650	0.90
	RGC 936	350	79.0	0.140	10500	7400	3100	1.42
	RGC 1003	280	43.5	0.112	8400	7400	1000	1.13
Busi (1)	Local	136		0.054	4080	6550	-2470	0.62
	RGC 1003	250	83.8	0.100	7500	7400	100	1.01

Table 5. Response of sorghum to scientific interventions on farmer's field

Village	Treatments	Grain yield (kg ha^{-1})	% increase over farmers' practice	WP (kg m^{-3})	Gross returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
Bhadarlao (4)	Farmers' practice (Local variety + No fertilizers)	700 (fodder)		0.116	3500	6550	-3050	0.53
	CSV 15 + fertilizers	2500 (fodder)	257	0.417	12500	7400	5100	1.69
Siyat (2)	Farmers' practice (Local variety + No fertilizers)	2000 (fodder)		0.545	10000	4500	5500	2.22
	CSV 15 + fertilizer	5500 (fodder)	175	1.499	27500	5100	22400	5.39
Busi (2)	Farmers' practice (Local variety + No fertilizers)	500 (grain) 3000 (fodder)		0.700	21000	6800	14200	3.09
	CSV 17 (For grain) + fertilizer	1200 (grain) 2100 (fodder)	140 -30	0.830	24900	7500	17400	3.32

Fertilizer dose - 40 kg N and 20 kg P_2O_5 ha^{-1}. *fodder + grain yields were converted into sorghum grain equivalent yield for calculating water productivity

Table 6. Response of sesame to improved varieties on farmer's field

Village	Variety	Grain yield (kg ha^{-1})	% increase over farmers' practice	WP (kg m^{-3})	Gross returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
Siyat (3)	Local	178		0.157	11592	4653	6938	2.49
	RT 127	300	68	0.196	19500	5033	14467	3.87
Busi (4)	Local	205		0.057	13325	4900	8425	2.72
	RT 127	333	62	0.092	21645	5300	16345	4.08

yielded Raj 3077 (under farmers practice) by 20 and 30%, respectively (Table 7). Also this was most preferred for its excellent chapatti making quality. It has resulted in additional income of Rs. 13500 ha^{-1} with the B:C ratio of 3.52-4.79.

Mustard: The trials were conducted in saline fields of Dhamli village (EC 6.7 dS m^{-1}). Amongst the salinity tolerant varieties GM 3 and CS 54, the GM 3 produced 22.4% higher grain yield over the later variety and 33% over established variety Bio 902 (Table 8). By replacing the variety, additional returns of Rs. 3800 ha^{-1} with a B:C ratio of 2.10 were obtained.

Water productivity

Improvement in yields was ultimately reflected in improved water productivity. The water productivity during kharif improved from 0.085-0.185 kg grain m^{-3} for improved cultivars of mung bean along with fertilizer application, sorghum 1.50-0.417 kg grain m^{-3}by sorghum variety CSV 15 and by 0.83 kg grain m^{-3} by CSV 17, kg grain m^{-3}, 0.08-0.14 by cluster bean and by 0.092-0.196 kg grain m^{-3}. In the irrigated rabi crops i.e. wheat and mustard, the water productivity achieved were 0.80-0.60 and 0.228-0.279 kg grain m^{-3}. Similar finding was

Table 7. Response of wheat to improved varieties on farmer's field

Village	Variety	Grain yield (kg ha^{-1})	% increase over farmers' practice	WP (kg m^{-3})	Gross returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
Bhaderlao Wheat (1)	Raj 3077 (Farmers' practice)	4000		0.667	75300	17350	57950	4.34
	Raj 4037	4800	20	0.800	90300	18850	71450	4.79
Dhamli Wheat (4)	Raj 3077 (Farmers' practice)	2450		0.469	56900	18900	38000	3.01
	Raj 4037	3175	30	0.608	71800	20400	51400	3.52

Table 8. Response of mustard to improved varieties on farmer's field

Village	Variety	Grain yield (kg ha^{-1})	% increase over farmers' practice	WP (kg m^{-3})	Gross returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
Dhamli Mustard (4)	Bio 902 (Farmers' practice)	900		0.209	11024	6125	4900	1.80
	GM 3	1200	33	0.279	14700	6125	8700	2.10
	CS 54	980	9	0.228	12005	6125	5880	1.96

also reported by Oswal (1994) and Teixeira and Bassoi (2009).

Post evaluation

The study showed that farmers do have multiple criteria for evaluating the varieties apart from yield, though the latter is the major parameter for recommending and releasing varieties for multi-locations. Farmers' preferred varieties were identified using preference ranking (Fischler and Wortmann, 1999). The preference ranking criteria were classified into four groups (i) grain yield-related criteria (ii) non-grain biomass related criteria (iii) environmental adaptability-related criteria (maturity period, tolerance to disease, ability to perform well in low fertile soils, ability to perform well under limited rainfall situation or matching with the local environment and stand ability), and (iv) farmers' perception-related criteria. Farmers identified earliness, yield, and quality as the main criteria for adoption and popularization of improved varieties of mung bean, sorghum, clusterbean, sesame, wheat and mustard. Varieties hence preferred were RMG 62 of mung bean, CSV 15 and CSV 17 of sorghum, RGC 936 of clusterbean, RT127 of sesame, Raj 4037 of wheat and GM3 of mustard.

A rapid survey in these villages and adjoining areas was conducted during 2012 i.e. after 2 years of completion of trials and it was found that variety CSV 17, of sorghum is now established in Sojat area, CSV 15 is most preferred and known dual purpose sorghum variety and its seed is now available in the market. Wheat variety Raj 4037 has become most popular variety of wheat in whole of the Pali district and is now being sown over a large area mainly because of very good grain quality over the then prevalent variety Raj 3077.

It may be concluded that participatory action research do not undermine the importance of on station research but supports it and generated confidence and awareness among farmers, researchers and extension workers and ultimately led to fast dissemination of technologies.

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