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POTENTIAL FOR CEREAL-BASED DOUBLE CROPPING IN BALE REGION OF SOUTHEASTERN ETHIOPIA

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ABSTRACT

A double cropping trial was conducted under bimodal rainfall conditions for two years at the Sinana Research Centre in southeastern Ethiopia. Compared to the traditional farmers' practice of fallowing land during one of the two annual cropping seasons, double cropping increased total farm grain output and net income. The best crop combination, both in agronomic and economic terms, consisted of field pea (*Pisum arvense* L.) grown during the first rainy season followed by bread wheat (*Triticum aestivum* L.) in the second season. Double cropping cereals in both seasons appeared to be the least desirable combination, although this system still outperformed the traditional fallow practice during the two years of this study. Double cropping in Sinana "woreda" district could minimize several negative aspects of the fallow system: (1) soil erosion could be reduced by maintaining a crop vegetative cover in both cropping seasons; (2) the rate of expansion of cultivation onto pasture land could be reduced by intensifying production on the currently cropped areas; (3) weed control could be facilitated by rotating non-cereal crops with the second season wheat crop; and (4) human and ox labour could be utilized more efficiently in a double cropping system than in a fallow-wheat system.

Key Words: **Barley, crop rotation, farming system, field pea, wheat.**

RÉSUMÉ

Un essai de culture intercalaire a été effectué dans des conditions de pluviosité bimodale pendant deux ans à Sinana Research Centre das le sud de l' Ethiopie. Comparée à la pratique triaditionnelle des fermiers qui cousiste à laisser le champ en jachère pendant une ou deux saisons de culture annuelle, la culture intercalaire a augmenté le rendement total en grain et le revenu net de la ferme. La meilleure combinaison culturale tant en termes agronomiques qu'en termes économiqus était de planter le pois (*Pisum arvense* L.) pendeant la premièré saison des pluies et le blé (Triticum aestium L.) pendant la deuxième. La culture intercalaire des ceréales dans les deux saisons a semblé être la moins bonne combinaison bien qu'elle a tonjours surpassé la traditionnelle mise en jachère pour les deux années de la présente étude. La culture intercalaire dans le district de Sinana "Woreda" a pu minimiser plusieurs effets négatifs du système de jachère : (1) l'érosion du sol a pu être réduite grâce au maintien de la couverture végétale par la culture; (2) le taux d'expansion de culture sur le terrain réservé au pâturage a été réduite par l'intensification de la production sur des espaces actuellement cultivés; (3) le contrôle de mauvaises herbes a été facilité par l'alternance des cultures non-

céréalières avec le blé en seconde saison; et (4) le travail de l'homme et du boeuf ont pu être rendus plus efficients en culture intercalaire que dans le système jachère -blé.

***Mots Clés*: Orge, culture en rotation, système agricole, pois, blé.**

INTRODUCTION

The production of bread wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) dominates the peasant farming systems in the mid to high altitude zones (i.e. >2000 m a.s.l.) of Ethiopia. The major constraints to crop production on peasant farms in these zones have been described, these being of low soil fertility, lack of seed of improved cultivars, poor land preparation, and inadequate weed control (Alemayehu and Franzel, 1987). Several agronomic interventions aimed at improving bread wheat production have been tested on-station and on-farm by staff of the Sinana Research Centre situated in Bale Region of southeastern Ethiopia (Tanner *et al.*, 1991).

In the Sinana "woreda" district of Bale Region, rainfall is distributed bimodally with the annual total of approximately 850 mm split roughly equally between two seasons — the first rains "belg" from March to July and the second rains "meher" from August to November (Alemayehu and Franzel, 1987). Both seasons are suitable for wheat and barley production, but drought stress is encountered frequently in this marginal rainfall zone. Most farmers prefer to plant bread wheat in the "meher" season to minimize the problem of grain sprouting (i.e. wheat matures during the dry December–January period); barley and field pea (*Pisum arvense* L.) are planted mainly in the "belg" season (Alemayehu and Franzel, 1987).

In the Sinana "woreda", few peasant farmers utilize both rainy seasons to produce two crops on the same piece of land — most prefer to fallow the land during one of the two annual cropping seasons (Alemayehu and Franzel, 1987), probably due to the narrow window of time separating the two seasons. The current practice necessitates frequent ploughing of the land during the fallow season to control weed growth, requiring a significant input of human labour and ox-power, and rendering the soil surface susceptible to erosion. Furthermore, increasing population pressure in Bale Region is prompting a conversion of land from semi-permanent pasture to arable cropping (Alemayehu and Franzel, 1987).

Few studies have been conducted on the potential of wheat-based double-cropping systems in Ethiopia. Jamal (1988) reported a technically feasible cotton-wheat double cropping system for the irrigated production zone in the Awash Valley. At the Holetta Research Centre, in Shewa Region of central Ethiopia, the potential for double-cropping was examined, but proved to be of limited feasibility given that the short (first) rains average only about 250 mm in this area (Tanner *et al.*, 1991). Double cropping at Ginchi, a Vertisol soil zone in Shewa Region, also proved to be unacceptable for several reasons (Tanner *et al.*, 1991).

To develop a feasible and acceptable double cropping system, several factors must be considered. The principal consideration is to have a cropping sequence with component crops that are compatible with the seasons, and which exhibit biological complementarity. Two studies examined the impact of various cropping sequences on the principal small grain crops in the Ethiopian highlands (Amanuel and Tanner, 1991; Hailu *et al.*, 1989). In both, leguminous species, in particular, exerted dramatic positive effects on the vigour and grain yield of succeeding wheat and/or barley crops.

Soil fertility is another important consideration in the development of a double cropping system. Double cropping has potential implications for the nitrogen requirement of and usage by the cereal component(s) (Hargrove *et al.*, 1983; Narwal *et al.*, 1983; Howard and Lessman, 1991), and, less frequently, on phosphorus use efficiency (Sinha *et al.*, 1983).

The research reported in this paper was conducted to determine the feasibility of double-cropping land in the Sinana "woreda".

MATERIALS AND METHODS

Three double cropping trials were conducted, one during 1990 and two during 1991 at the Sinana Research Centre in Sinana "woreda" of Bale Region. The soil is classified as a pellic Vertisol, and the altitude is 2400 m a.s.l. (Alemayehu and Franzel, 1987).

Five precursor crops, specifically emmer wheat (*Triticum dicoccum* L.), bread wheat (cv. Wollandi), barley (cv. Aruso), linseed (*Linum* *usilatissimum* L. cv. CI 1652), and field pea (cv. G22763-2C), were planted in the 1990 "belg" season (April-July) according to the farmers' preferred sowing date (i.e. early April).

All "belg" (first) season crops were managed to imitate farmers' practice. The trial area, including the plots designated for fallow, was ploughed by the local ox-plough ("maresha") three times prior to sowing. "Belg" plots measured 10 x 10 m, and were laid out in a Randomized Complete Block Design with three replications. Seed rates of 125, 125, 100, 25 and 150 kg ha^{-1} were used for emmer, bread wheat, barley, linseed, and field pea, respectively. All "belg" season crops received a uniform application of 50 kg diammonium phosphate (DAP) ha^{-1} (9-10 kg N-P ha^{-1}) broadcast at sowing. No fertilizer was applied to the fallow plots. Subsequent to broadcasting seed and fertilizer, the trial area was ploughed once more to cover the seed. All crops were hand-weeded once to simulate farmers' practice. Precursor crops were harvested at ground level to facilitate the measurement of crop biomass.

On the "belg" season fallow plots, weeds were harvested manually as soon as they reached 20–40 cm in height, and before they flowered. This operation was designed to simulate the removal of weed biomass by grazing animals as normally occurs in farmers' fallow fields. Two harvests in this manner were necessary to remove weed growth during each of the 1990 and 1991 "belg" seasons.

Subsequent to the harvest of the latest maturing "belg" season crop, the trial area was ploughed once for seedbed preparation, using the local plough. Seed and fertilizer were then broadcast, and covered by one pass with the plough. In the "meher" (second) season, all plots were planted to the bread wheat cv. ET13 at a seed rate of 125 kg ha^{-1}. Fertility subplots were established on each main plot (i.e. consisting of the plots used for the "belg" season crops), having nutrient levels of 0-0, 0-20 and 41-20 kg N-P ha^{-1}. Subplot sizes were 5 x 5 m. Subplot treatments were randomly assigned to main plots. Weeds were controlled in the "meher" wheat crop by spraying a post-emergence broadleaf herbicide (Brittox^{R} 52.5 EC: 525 g ioxynil + bromoxynil + MCPP l^{-1}: Rhone Poulenc) at a product rate of 3 l ha^{-1} followed by one supplementary hand-weeding.

In 1991, the trial was repeated in both seasons, and duplicated with one set of treatments being situated on the subplots established in 1990, while a second set was initiated on a new site at the Sinana Research Centre.

Data collected on a subplot basis in both seasons of each year included days to crop emergence and maturity, plant height, spike counts (for wheat), weed counts, and disease scores. A net plot of 3 x 3 m was harvested at ground level to facilitate the determination of biomass and grain yield, and harvest index. Thousand kernel weights (TKW) were measured from the grain harvested from each net plot. Grains $spike^{-1}$ and grains m^{-2} were calculated from the data measured on each subplot.

All data were subjected to analysis of variance using a split-plot model, and means were separated using the LSD test at the 5% level (unless otherwise specified).

Partial budget analysis, according to the methodology of CIMMYT (1988), was conducted in the local currency, Ethiopian Birr (EB), and was based on the following assumptions:

- crop yields were reduced by 20% to avoid overestimation of yield in researcher-managed trials as per Amanuel *et al.* (1991);
- gross benefits were calculated on the basis of Nov., 1993 market prices in Sinana woreda for emmer (0.5 EB kg^{-1}), bread wheat (0.825), barley (0.625), linseed (1.50), and field pea (1.50);
- the cost of harvesting and threshing was taken at 0.13 EB kg^{-1} of grain harvested;
- hand weeding by farmers was assumed to require 18 work-days ha^{-1} (Tanner *et al.*, 1993) at a daily cost of 3.5 EB;
- the cost of broadcasting seed and fertilizer and incorporating both by "maresha" was taken to be 4.2 EB ha^{-1};
- field prices for N and P from DAP were taken as 4.04 EB kg^{-1} of nutrient; and
- wheat straw was not valued because of the lack of demand for it in Bale Region.

The partial budget approach is a useful method to evaluate the profitability of a technological innovation; the marginal returns achieved with a new technology must be compared to the marginal cost of adopting the technology (CIMMYT, 1988).

RESULTS

Climatic conditions. Seasonal climatic conditions during 1990 and 1991 were representative of the normal variation encountered in Sinana "woreda" (Alemayehu and Franzel, 1987). The "belg" cropping seasons received 345.0 and 360.8 mm of rainfall in 1990 and 1991, respectively, while the corresponding "meher" seasons received 427.6 and 343.5 mm. The monthly rainfall totals, and monthly mean minimum and maximum temperatures are presented in Fig. 1.

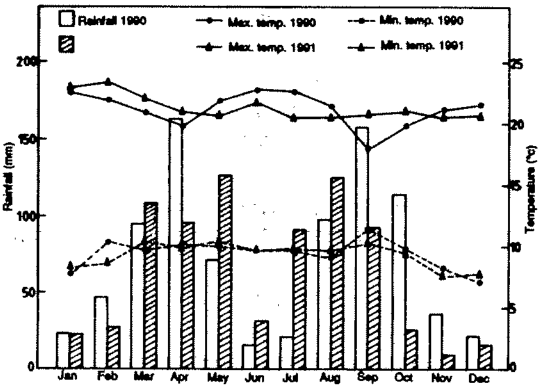

Figure 1. Climatic parameters for Sinana woreda in southeastern Ethiopia during 1990 and 1991.

First season crops. The agronomic parameters for the "belg" season crops over the three seasons were combined and are presented in Table 1. The "belg" season crops included in the trial matured from 81 to 111 days post-emergence, with barley maturing the earliest, followed in succession by emmer wheat, field pea, bread wheat, and linseed (Table 1).

Grain yields of bread wheat and barley were reduced by poor stand development in the 1990 "belg" season, primarily due to barley shoot fly (*Delia flavibasis* Stein) attack. This problem did not reoccur in 1991, resulting in dramatically higher grain yields for wheat and barley.

The high grain yield shown for emmer wheat (Table 1) represents the yield of uncleaned seed (i.e., including hulls and attached spikelet segments); the process of cleaning emmer wheat seed may remove up to 50% of the weight of the uncleaned seed. On the local grain market, emmer wheat is priced on an uncleaned basis, so the uncleaned yields were used for subsequent economic analyses.

In the 1991 "belg" season trial sown for the second consecutive year on fixed plots, only biomass yield demonstrated residual response to the fertilizer applied to the 1990 "meher" wheat crop (data not presented). Biomass yields were higher following the 41-20 nutrient subplots compared to the 0–20 subplots; the 0–0 subplots were intermediate in yield and not significantly different from either of the other two rates. No differences were observed in plant height, grain yield or harvest index of the precursor crops in response to the residual fertility effects. Emmer wheat and barley appeared to be the most responsive to residual fertility.

Second season wheat crop. The yield parameters measured on the "meher" season wheat plots are presented in Tables 2–4, representing the 1990 crop (Table 2), the 1991 second consecutive cycle (Table 3), and the 1991 first cycle crop (Table 4).

TABLE 1. Agronomic parameters of the precursor crops grown in the first cropping seasons ("belg") of 1990 and 1991 (mean of 3 trials)

	Height (cm)	Grain yield (kg ha^{-1})	Biomass yield (kg ha^{-1})	Harvest index (%)	Days to maturity
Emmer wheat	86	2332[a]	8156	28.6[a]	93
Bread wheat[b]	108	1393	7285	19.1	106
Barley	96	2023	9289	21.8	81
Linseed	81	1010	5946	17.0	111
Field pea	113	1384	7516	18.4	99

[a] Based on the weight of hulled seed.
[b] Farmers' local bread wheat variety Wollandi (i.e. an unimproved variety).

TABLE 2. Yield parameters of ET13 bread wheat grown in the second cropping season ("meher") of 1990 after six precursors in the first season and under 3 fertility levels

	Spikes m^{-2}	TKW (g)	Grains $spike^{-1}$	Grains m^{-2}	Grain (kg ha^{-1})	Biomass (kg ha^{-1})
Precursor	NS	$P < 0.10$	$P < 0.10$	*	*	$P < 0.10$
Emmer	336	32.8 B	11.4 B	3823 B	1270 B	4630 B
Bread wheat	417	35.6 A	18.3 A	7374 A	2625 A	8358 A
Barley	416	36.2 A	18.1 A	7195 A	2616 A	8951 A
Linseed	429	34.7 AB	15.3 AB	6588 A	2288 A	8210 A
Field pea	496	36.3 A	15.6 A	7654 A	2767 A	9185 A
Fallow	436	35.3 A	14.8 AB	6510 A	2320 A	7407 A
LSD($P = 0.05$)	NS	1.9[a]	4.0[a]	2326	895	2485[a]
Fertilizer	*	NS	NS	NS	NS	***
0–0	418 AB	34.7	15.9	6640	2343	7753 B
0–20	394 B	35.2	16.0	6196	2200	6858 C
41–20	453 A	35.6	14.9	6735	2400	8759 A
LSD($P = 0.05$)	44	NS	NS	NS	NS	870
Mean	422	35.2	15.6	6524	2314	7790

[a]: LSD value at the $P = 0.10$ level of significance.
*, ***: Significant at $P = 0.05$ or $P = 0.001$, respectively; NS: non-significant.
Means within the same column and factor heading followed by the same letter or by no letters do not differ significantly by the LSD test.

TABLE 3. Yield parameters of ET13 bread wheat grown in the second cropping season ("meher") of 1991 after six precursors in the first season and under 3 fertility levels (for the second consecutive year)

	Spikes m^{-2}	TKW (g)	Grains $spike^{-1}$	Grains m^{-2}	Grain (kg ha^{-1})	Biomass (kg ha^{-1})
Precursor	NS	NS	NS	NS	NS	NS
Emmer	350	36.3	11.0	3823	1385	5125
Bread wheat	330	35.9	12.2	4066	1465	4892
Barley	300	37.2	12.0	3575	1329	4886
Linseed	368	35.8	13.3	4773	1704	5724
Field pea	432	35.2	12.9	5637	1969	6689
Fallow	357	35.7	15.3	5391	1928	6218
LSD($P = 0.05$)	NS	NS	NS	NS	NS	NS
Fertilizer	$P < 0.10$	NS	*	NS	NS	$P < 0.10$
0–0	332 B	35.8	14.1 A	4677	1670	5528 AB
0–20	354 AB	36.4	12.3 B	4350	1573	5188 B
41–20	382 A	35.8	12.0 B	4606	1648	6052 A
LSD($P = 0.05$)	34[a]	NS	1.7	NS	NS	645[a]
Mean	356	36.0	12.8	4544	1630	5589

[a]: LSD value at the $P = 0.10$ level of significance.
*: Significant at $P = 0.05$; NS: non-significant.
Means within the same column and factor heading followed by the same letter or by no letters do not differ significantly by the LSD test.

Precursor crop by fertilizer interaction was non-significant for all parameters in each trial, and, thus, was omitted from the tables.

During the 1990 "meher" season, bread wheat sown after emmer wheat exhibited poor vigour, an observation substantiated by the significantly reduced grain and biomass yields (Table 2) relative to all of the other precursors (which did not differ from each other). The highest yield obtained was 2767 kg ha^{-1} for wheat after field pea. The reduction in the yield potential of bread wheat grown after emmer wheat appears to have been manifested during all phases of the crop growing cycle as seen in the reductions in grains m^{-2}, harvest index,

TABLE 4. Yield parameters of ET13 bread wheat grown in the second cropping season ("meher") of 1991 after six precursors in the first season and under 3 fertility levels (for the first year)

	Spikes m^{-2}	TKW (g)	Grains $spike^{-1}$	Grains m^{-2}	Grain (kg ha^{-1})	Biomass (kg ha^{-1})
Precursor	*	NS	**	**	**	**
Emmer	226 B	33.8	15.7 A	3202 B	1073 B	4034 B
Bread wheat	313 A	34.7	6.4 C	1999 C	704 BC	2573 BC
Barley	314 A	33.1	6.3 C	1952 C	653 C	2347 C
Linseed	345 A	34.2	8.6 BC	3115 BC	1081 B	4164 B
Field pea	375 A	35.2	12.2 AB	4555 A	1617 A	5794 A
Fallow	361 A	35.7	8.4 BC	2956 BC	1055 BC	3956 B
LSD(P = 0.05)	79	NS	4.8	1175	410	1606
Fertilizer	NS	NS	$P < 0.10$	*	*	**
0–0	328	34.1	8.3 B	2672 B	922 B	3374 B
0–20	298	34.9	9.8 AB	2848 AB	1011 AB	3662 B
41–20	341	34.3	10.8 A	3370 A	1158 A	4398 A
LSD(P = 0.05)	NS	NS	1.9[a]	543	183	549
Mean	322	34.4	9.6	2963	1030	3811

[a]: LSD value at the $P = 0.10$ level of significance.
*, **: Significant at $P = 0.05$ or $P = 0.01$, respectively; NS: non-significant.
Means within the same column and factor heading followed by the same letter or by no letters do not differ significantly by the LSD test.

grains $spike^{-1}$, thousand kernel weight (TKW), spikes m^{-2} (N.S.), and plant height (N.S.) relative to all or the majority of the other precursors. Fertilizer N increased wheat biomass yield, plant height, and spike density. As harvest index was reduced, wheat grain yield was not significantly affected. This is consistent with previous reports indicating that N response in Sinana "woreda" is seldom significant or economic, particularly on farmers' fields (Lemma *et al.*, 1992; Zewdu *et al.*, 1992).

The grain yields of both trials conducted in the 1991 "meher" season were low, reflecting the reduced rainfall received compared to 1990. In the 1991 "meher" wheat trial that was superimposed on the 1990 subplots, no crop parameters other than height were significantly affected by precursors (Table 3). Nonetheless, wheat after field pea exhibited the highest mean yield (1969 kg ha^{-1}); wheat after emmer, wheat or barley produced the lowest grain yields as could logically be expected from a cereal-cereal cropping sequence (de Boer *et al.*, 1993). As in the 1990 "meher" wheat trial, fertilizer N increased biomass yield, plant height, and spike density, but reduced harvest index; thus, there was no significant effect of fertilizer N on wheat grain yield.

For the 1991 "meher" trial conducted on the new field site, most crop parameters were significantly improved following the field pea precursor crop, and reduced following the cereal precursors (Table 4). Grain and biomass yields following a field pea precursor were significantly increased relative to all other precursors. Fertilizer N significantly increased grain yield, biomass yield, grains m^{-2}, grains $spike^{-1}$, and plant height. However, the small magnitude of the response to fertilizer N agrees with previous reports of the lack of economic response to N in Sinana woreda (Amanuel *et al.*, 1991; Lemma *et al.*, 1992).

Economic analysis. The partial budget analysis of the double cropping trial was based on adjusted mean grain yields of "belg" and "meher" season crops across the three trials included in this study. Furthermore, since fertilizer had no significant effect on the grain yield of the "meher" season wheat crop in two of the three trials, only the yields of the unfertilized subplots were utilized for "meher" season wheat.

The partial budget analysis indicated that all double cropping systems produced higher gross and net benefits compared to the traditional system of fallowing. The highest net benefits (Table 5) were obtained from double cropping with non-cereal crops in the "belg" season (i.e., field pea and linseed).

Comparing the marginal rates of return (MRRs) for the double cropping treatments (Table 5)

TABLE 5. Marginal rate of return (MRR) analysis of the double cropping trial

Precursor treatment	Marginal TVC[a] (EB[c] ha^{-1})	Total costs (EB ha^{-1})	Marginal NB[b] (EB ha^{-1})	NB[b] (EB ha^{-1})	MRR (%)
Fallow	178		950		
		195		295	151
Emmer wheat	373		1245		
		62		321	518
Bread wheat	435		1566		
		9		69	767
Barley	444		1635		
		34		216	635
Linseed	478		1851		
		108		658	609
Field pea	586		2509		

[a]: Total variable costs.
[b]: Net benefit.
[c]: 1 U.S. $ = 6.29 Ethiopian Birr (EB) on May 24, 1994.

revealed that variable costs and net benefit increased in the same ranking order (viz. fallow, emmer, bread wheat, barley, linseed, field pea), and that all treatments were non-dominated with an associated MRR greater than 100%. This analysis indicates that double cropping is an economically feasible alternative to the traditional fallow-wheat system. While all potential "belg" season crops included in this study increased net benefit relative to fallowing, profitability was optimized by growing short season, non-cereal crops such as field pea or linseed.

DISCUSSION

On the basis of its agronomic effects on "meher" season wheat, the leguminous precursor (field pea) was the most beneficial "belg" season crop. Previous studies in Ethiopia have indicated the benefits of rotating wheat with legumes (Hailu *et al.*, 1989; Amanuel and Tanner, 1991). In the present study, since both response to fertilizer and the interaction between precursors and fertilizer levels were generally nonsignificant, it is unlikely that the benefit from the leguminous precursor was due solely to nitrogen fixation.

In general, wheat sown after any cereal performed poorly, reflecting either an allelopathic effect of decomposing cereal straw as reported elsewhere (Dias, 1991), or deterioration in soil properties.

It is apparent that double cropping is a feasible option in Sinana "woreda" of Bale Region. The best agronomic and economic results were obtained with "meher" season bread wheat following a "belg" crop of field pea; the poorest results were obtained with wheat following "belg" cereal crops, although this system outperformed the traditional fallow practice.

Double cropping in Sinana "woreda" could minimize several negative aspects of the fallow system: (1) soil erosion could be reduced by maintaining a crop vegetative cover in both annual cropping seasons; (2) the rate of expansion of cultivation onto pasture land could be reduced by intensifying production on the currently cropped areas; (3) weed control could be facilitated by rotating non-cereal crops with the "meher" wheat crop; and (4) human and ox labour could be utilized more efficiently in a double cropping system than in a fallow-wheat system.

A reduction in fallow land will undeniably decrease the potential area for grazing livestock. However, as the principal feed shortage in Sinana "woreda" occurs during the annual dry season (January-March) (Alemayehu and Franzel, 1987), reducing the area of fallow during the "belg" and "meher" seasons may not have a significant impact on livestock grazing. Furthermore, the double cropping system has the potential to increase the total quantity of crop residues available for livestock feed.

The results of this study were surprising in that fallowing the land during the "belg" season did not provide any apparent benefit to the "meher" wheat crop. Multi-location, on-farm trials of three years' duration are planned to compare double cropping, based on "belg" season field pea and barley combined with "meher" season wheat, to the traditional "belg" season fallow; soil moisture and fertility regimes will be monitored closely. Farmer assessment of the potential for double cropping will be elicited.

Further detailed studies are required to assess the impact of double cropping on water use efficiency (Deibert *et al.*, 1986; Fischer *et al.*, 1990), on disease (de Boer *et al.*, 1993) and weed incidence (Heenan *et al.*, 1990), and on soil physical (McFarland *et al.*, 1990) and chemical (Howard and Lessman, 1991; Sinha *et al.*, 1983) properties. Furthermore, the current study did not consider modified crop establishment methods which may be required to facilitate timely operations in a double cropping system (Griffin and Taylor, 1986; Jamal, 1988).

The ultimate adoption of double cropping by individual farmers will be influenced by their perception of the capacity to increase farm income while diversifying the risk of crop failure (Shapiro *et al.*, 1992).

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