Variety, fertilisers, weed control and clover mixture effects on bread wheat in Ethiopia

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Einfluß von Sorte, Düngung, Unkrautbekämpfung und Kleeuntersaat auf Weichweizen in Äthiopien

1. Introduction

Bread wheat *(Triticum aestivum* L.) is an important cereal crop in Ethiopia. Low bread wheat peasant farm level yields in the highlands of Ethiopia have prompted the development of improved site specific bread wheat management options which, inter alia, include high yielding varieties, optimum sowing dates, seeding rates, seed bed preparation, N and P fertiliser application, and weed control. Whereas research work on determination of the relative importance of these factors and economic optimum levels thereof for specific production systems continue, new technological components such as cultivation of bread wheat and clover *(Trifolium* sp.) in mixtures are recently being promoted.

In a crop-livestock mixed farming system where land is scarce, integration of forage legumes into cereal crops may help achieve sustained and improved agricultural production. In Ethiopia, stubble left after food crop harvest is used for grazing livestock in the dry season when feed is in short supply. ABATE et al. (1992, 1994) and KAHURANANGA (1991) demonstrated the potential of improving after-crop-harvest stubble through the cultivation of clovers in mixtures with wheat in the central highlands of Ethiopia.

Growing forage legumes in mixtures with cereals, besides providing nutritious crop residue for the livestock, may protect the soil against erosion, fix nitrogen for the cereal crop and can deter the development of weeds, insect pests and diseases that would prevail in the cereal monoculture. Several workers (KAHURANANGA, 1991; ABATE et al., 1992,

Zusammenfassung

Die Wirkungen und Wechselwirkungen von Sorte, N, P, Kleeuntersaat und Unkrautbekämpfung auf Weichweizen wurden in einem 2^5 randomisierten kompletten Block mit 2 Wiederholungen auf Nitosol in Holetta, Äthiopien, in den Jahren 1993 and 1994 untersucht. Ein Sortenwechsel, die N oder P Düngung oder die Unkrautbekämpfung hoben den Kornertrag um 23, 17, 42 bzw. 20 % an. Eine 63 %-ige Ertragserhöhung brachte die Kombination von N und P, während Sortenwechsel, N und P zusammen zu einer Ertragsverdoppelung führten. Die Summenwirkung von N, P und Unkrautbekämpfung machte 129 % aus. Der Trockenmasseertrag von Klee wurde durch N vermindert, aber durch Unkrautbekämpfung verdoppelt. Durch üppiges Wachstum des Weizens in beiden Jahren kam es zu sehr geringen Klee-Erträgen.

Schlagworte: Äthiopien, Weizen, Stickstoff, Phosphor, Unkrautbekämpfung.

Summary

The actions and interactions of varieties, N, P, clover and weed control on bread wheat were studied in a 2^5 factorial in randomised complete block design experiment with two replications on Nitosols of Holetta, Central Ethiopia in 1993 and 1994 seasons. A change in variety, N or P application and weed control increased wheat grain yield by 23, 17, 42 and 20 %, respectively. N and P together increased grain yield by 63 %, while variety + N + P doubled the yield. The combined effect of N, P and weed control increased grain yield by 129 %. Clover dry matter yield was reduced by N but doubled by weed control. Each season, the wheat crop grew vigorously resulting in a very low clover yield.

Key words: Ethiopia, wheat, nitrogen, phosphorous, weed control.

1994) have reported variable results on the effect of clover mixtures on wheat yield. On drained vertisols, ABATE et al. (1992) noted lack of adverse effect of clovers on wheat grain yield. On well drained red brown clay loam of Holetta, KAHURANANGA (1991) reported similar findings when both wheat and clovers were row seeded. Wheat grain yield, however, was reduced when the clovers were broadcast in row seeded wheat. In the same study, P fertiliser increased yield significantly especially that of the legume component. In another study on vertisols, ABATE et al. (1994) reported similar wheat yields with or without clover at Deneba, while wheat grain yield was significantly reduced due to the presence of clovers at Ginchi. In this study, sole wheat receiving N fertiliser yielded more than wheat grown in mixtures with clover but without additional N. In all the above cases, however, the total crop residue yield was significantly increased due to the addition of clovers in the wheat crop.

Studies conducted by AMSAL et al. (1997) to determine the effects of crop management factors in four priority wheat production zones of Ethiopia indicated an increase of 13 – 315 % due to improved variety, 20–88 % due to the application of 60 N + 26 P kg/ha fertiliser, and 17–94 % due to hand weeding. At Holetta, response to fertiliser application averaged 83 % over two years, representing a conversion ratio of about 14.4 kg grain per kg nutrient. Response to weeding was significant in one out of two years giving rise to a 30 % yield increase. The interaction of weed control and fertiliser application was significant in one of the years with weeding markedly improving fertiliser use efficiency. Whereas this study did not determine the relative contribution of N or P fertiliser alone, information on, whether bread wheat-clover mixture as a management factor would interact with other bread wheat crop management factors such as fertilisation and weed control using varieties with differing morphology is scanty. The aim of this experiment was, therefore, to study the effects and interactions of variety, nitrogen, phosphorous, clover mixture and weed control on Nitosol of Holetta.

2. Materials and methods

The trial was conducted on well drained red brown clay loam, a Nitosol, of Holetta Research Centre (altitude 2390 m a.s.l., latitude 9° 03'N, longitude 38° 31'E) in the central highlands of Ethiopia. Two varieties (the semi-dwarf Dashen or the taller ET-13), N (0 or 60 kg/ha as urea), P_2O_5 (0 or 60 kg/ha as triple super phosphate), in a 2^5 randomised complete block design with two replications. Wheat was seeded at a rate of 150 kg/ha and clover at a rate of 12 kg/ha. While wheat was hoed after broadcasting, clover was broadcast only right after covering the wheat. In the weeded treatments, weeds were removed once by hand, about a month after sowing. The clover species was *Trifolium quartinianum* obtained from the Forage and Pasture Research Section of the Holetta Research Centre. A plot size of 2 m x 5 m was used of which the central 3.6 m^2 was used for yield determination. Seeding dates were June 25 in 1993 and June 23 in 1994 and harvesting dates were December 7 in 1993 and November 22 in 1994. A composite soil sample was collected from a 0–20 cm depth right before planting, and the pH and nutrient status of the soil were determined at Holetta Research Centre Plant and Soil Analysis Laboratory. The soil had a pH of 4.7, organic carbon of 1.76 %, N of 0.16 % and P_2O_5 of 16.5 mg/kg (Bray II). At harvest, soil samples were collected from the same depth of each plot from a single replication to see the effect of the treatment factors on the soil pH, organic matter, total N, and available P and K. These data were analysed as a 2^5 factorial in randomised complete blocks (RCB) using the MSTAT statistical package (MSTAT, 1989). Since these data were collected only from a single replication, all the three or more factor interactions were used to estimate the experimental error. As a result, only the five main effects and the ten two-factor interactions were evaluated statistically.

Clover count, in both years, was taken 41 days after planting and just before imposing the weeding treatment by throwing randomly a 0.25 m x 0.25 m quadrate at four spots in a plot. Data for clover count were log transformed for analysis. After carrying out separate analysis for each year, data were combined for the two years as variances were found homogeneous. Air-dried above ground dry matter (DM) weight of clover was also measured in 1993, and analysed using the same design and statistical package after log transformation. As weeding treatment was imposed after the clover count was taken and since clover count could not be made in the sole wheat plots, the main effects of these two factors (weeing and clover) were not statistically analysed. Data for grain yield were combined across years as the variances were homogeneous. Air-dried DM data of wheat were not combined for the two years as the variances were heterogeneous. All the data recorded on wheat were analysed as a 2^5 complete factorial in RCB with two replications using the same statistical package.

3. Results and discussion

3.1 Grain yield

The main effects of variety, N and P were significant each year and when combined over years (Table 1). Averaged over years, the taller (ET-13) out yielded Dashen by 23 % whereas the application of N or P gave a yield increase of 17 and 42 %, respectively. When averaged over years, clover and weed control, the combined effects of variety, N and P nearly doubled the grain yields of wheat (1530 vs. 3040 kg/ha). N and P together increased yield by 63 % over the no-fertiliser control translating to a nutrient conversion ratio that averaged 12.4 kg grain per kg nutrient. These results compare well with those of AMSAL et al. (1997) who reported a nutrient conversion ratio of 12.1 to 16.6 kg grain per kg nutrient using the same fertiliser rates as ours. The effects of weed control and clover were significant in 1994 but not in 1993 or when combined over the two years. Clover additions did not significantly interact with year, indicating a more or less stable performance each year. Response to weed control, however, was variable over years as indicated by a highly significant weed control by year interaction and, therefore, response in each year should be treated differently. Weed control brought a yield increase of 20 % in 1994. A similar effect was not apparent in 1993. Nevertheless, the experimental plots in 1993 were quite weedy when the weeding treatment was imposed. Such anomaly, we think, was caused by late weeding, after significant damage was inflicted on the crop. AMSAL et al. (1997) also reported a significant effect of weed control in one out of two years with a yield increase of 30 %. In 1994, the year of significant weed control effect, averaged over varieties and clover, the combined effects of N, P and weed control increased grain yield by 129 % (1360 vs. 3110 kg/ha).

Combined over years, a total of 57 interactions were estimated out of which only seven were statistically significant ($P < 0.05$). The two factor interactions of variety x P, variety x clover, clover x N, clover x P, clover x weeding, weeding x N and weeding x P were not significant each year and when combined over years. In this study, the additions of clover did not reduce grain yields, irrespective of variety. Consistent with this finding ABATE et al. (1992) also reported the lack of significant interaction between wheat and clover in a mixture.

The only significant two-factor interactions were variety x N in 1993, and variety x weeding and N x P in 1993 and when combined over the years (Table 2). While N significantly increased grain yields of ET-13 in both years with a conversion ratio of 10.4 and 6 kg grain per kg N in 1993 and 1994, respectively, a positive response to N application on Dashen giving rise to a ratio of 6.3 kg grain per kg N was observed in 1994 only. Combined over years, the N x P

Table 1: Variety, N, P, clover and weed control effects on above ground dry matter (DM) and grain yield of bread wheat at Holetta
Tabelle 1: Einfluß von Sorte, N, P, Klee und Unkrautbekämpfung auf Trockenmasse und Kornertrag von Weichweizen in Holetta

Factor	Level	DM (kg/ha)			Grain yield (kg/ha)		
		1993	1994	Mean	1993	1994	Mean
Variety	Dashen	6100	5520	5810	1900	1880	1890
	ET-13	8190**	6820**	7500**	2430**	2230**	2330**
N	–	6670	5690	6180	2020	1870	1940
	+	7620*	6640**	7130**	2310*	2230**	2270**
P	–	6370	4620	5500	1930	1550	1740
	+	7920**	7720**	7820**	2400**	2550**	2480**
Clover	–	7370	5920	6640	2180	1920	2050
	+	6930	6420	6670	2160	2180*	2170
Weeding	–	7130	5750	6440	2220	1860	2040
	+	7160	6590**	6880	2110	2240**	2180
SE		297	209	182	87	86	61
CV %		23.53	19.16	21.83	22.75	23.83	23.28

*; ** significant difference between the levels of a factor at 5 % and 1 %, respectively

Table 2: The effects of some selected two-factor combinations on the above ground dry matter and grain yield of bread wheat at Holetta
Tabelle 2: Die Einflüsse ausgewählter zweifaktorieller Kombinationen auf den Trockenmasse- und Kornertrag von Weichweizen in Holetta

Factor combination		DM(kg/ha)			Grain yield (kg/ha)		
		1993	1994	Mean	1993	1994	Mean
Variety	N	*		*	*		
Dashen	–	6200	5000	5600	1925	1687	1806
Dashen	+	6006	6037	6022	1881	2062	1972
ET-13	–	7144	6387	6766	2119	2044	2081
ET-13	+	9231	7250	8241	2744	2406	2575
Variety	Clover	*					
Dashen	–	5781	5331	5556	1800	1794	1797
Dashen	+	6425	5706	6066	2006	1956	1981
ET-13	–	8950	6512	7731	2556	2050	2303
ET-13	+	7425	7125	7275	2306	2400	2353
Variety	Weeding						*
Dashen	–	6219	5275	5747	2081	1744	1912
Dashen	+	5987	5762	5875	1725	2006	1866
ET-13	–	8037	6219	7128	2362	1969	2166
ET-14	+	8337	7419	7878	2500	2481	2491
N	P	**		**	**		**
–	–	6662	4194	5428	1994	1406	1700
–	+	6681	7194	6937	2050	2325	2187
+	–	6081	5044	5562	1869	1687	1778
+	+	9156	8244	8700	2756	2781	2769
Weeding	N		*				
–	–	6825	5606	6216	2144	1762	1953
–	+	7431	5887	6659	2300	1950	2125
+	–	6519	5781	6150	1900	1969	1934
+	+	7806	7400	7603	2325	2519	2422
Clover	Weeding		**	*			
–	–	7394	5994	6694	2381	1837	2059
–	+	7337	5850	6594	2075	2006	2041
+	–	6862	5500	6181	2162	1875	2019
+	+	6987	7331	7159	2150	2481	2316
SE		420	295	257	123	122	87

*; ** significant interactions between the factors at 5 % and 1 %, respectively

interaction was highly significant, and was not altered in time as the year x N x P was not significant. Averaged over years, P in the absence of N increased grain yield by about 29 %, whereas the same increase was about 56 % when N was present. Hence the interaction was positive and highly significant.

The N x clover interaction was not significant each year indicating the absence of antagonism between the effects of these factors. Averaged over years, variety, P and weed control, the presence of clover slightly increased wheat grain yields regardless of N application. Grain yield with both clover and N application was greater, and that with none was less, than either of these applied alone. Hence, the effects of N and clover were synergistic. Grain yield without N but with clover, however, was less than that with N only. ABATE et al. (1994) also reported similar findings on black Vertisols.

Particularly in 1994, there was an indication that the interactive effects of clover and weed control warrant further study. Averaged over variety, N and P, grain yields of wheat were similar under sole or mixtures when weeds were not controlled. With weeding, however, grain yields were greater by about 500 kg/ha in intercrop than in sole wheat. Conversely, the positive effect of weed control on wheat grain yield was greater in mixture than in sole (200 vs. 600 kg/ha).

3.2 Above ground wheat dry matter yield (DM)

This generally followed the patterns observed for grain yield. The main effects of variety, N and P were significant in both years (Table 1). DM yield increased by 29 % due to variety, 15 % due to N and 42 % due to P fertiliser. The effect of weed control was significant in 1994 only. Clover mixture did not have a significant effect in either year. Out of the 26 interactions evaluated each year only four in 1993 and three in 1994 were significant. None of the interactions were consistent over years, however. The three interactions observed in 1994 involved weed control, and three of the four interactions in 1993 were with N (Table 2).

Of the ten two-factor interactions, variety x P, variety x weed control, clover x N, clover x P and weed control x P were not significant each year. Variety x N, variety x clover, and N x P were significant in 1993, but not in 1994 (Table 2). Trends in DM yields for these interactions were similar to those of grain yield. Weed control x N and weed control x clover were significant in 1994 only. N application increased DM yields regardless of weed control in 1993. In 1994 the same increase was low without weed control and high with weed control. Likewise, the effect of weeding was pronounced only when clovers were present.

3.3 Other agronomic attributes

Variety, N and weed control had a highly significant effect on plant height (Table 3). On average, ET-13 was 20 cm taller than Dashen. Plants were 6 cm taller with N application or weed control than the respective controls. P application promoted growth in height by about 4 cm.

The main effects of variety, N, P and weed control were highly significant for spike length (Table 3). The main effect of clover addition, however, was not.

Variety and N application significantly increased seeds per spike. Dashen had eight more seeds per spike than ET-13. There were three more seeds when N was applied than when not. The main effects of P, clover and weed control were not significant (Table 3).

Variety, N, P and weed control significantly influenced 1000 seed weight (Table 3). Seeds of ET-13 were more plump than seeds of Dashen. N or P application increased 1000 seed weight, weeding significantly ($P < 0.05$) reduced the same. The reason for the latter case was not understood. The effects of clover addition and almost all the interactions were not significant.

Table 3: Average effects of variety, N, P, clover and weed control on the yield and some agronomic attributes of bread wheat, Holetta, 1993
Tabelle 3: Durchschnittliche Einflüsse von Sorte, N, P, Klee und Unkrautbekämpfung auf den Ertrag und einige pflanzenbauliche Faktoren in Holetta 1993

Factor	Level	Plant height (cm)	Spike length (cm)	Seeds spike^{-1}	TKW° (g)	DM (kg/ha)	Grain yield (kg/ha)
Variety	Dashen	89	8.9	54.6	27.4	6100	1900
	ET-13	109**	7.2**	42.6**	32.7**	8190**	2430**
N	–	96	7.8	47.1	29.2	6670	2020
	+	102**	8.3**	50.1**	30.9*	7620*	2310*
P	–	97	7.9	47.7	29.3	6370	1930
	+	101*	8.2*	49.5	30.8	7920**	2400**
Clover	–	99	8.1	49.2	29.8	7370	2180
	+	99	8.0	48.1	30.2	6930	2160
Weeding	–	102	7.9	48.5	32.5	7130	2220
	+	96**	8.2**	48.8	27.5**	7160	2110
SE		0.90	0.07	0.70	0.50	297	87
CV%		5.25	5.2	8.69	9.67	23.53	22.75

*; ** significant difference between the levels of a factor at 5 % and 1 %, respectively
° thousand kernel weight

3.4 Clover count and dry weight

In both years, there was no significant difference in the number of clover plants counted 41 days after seeding due to the main effects of variety, N, P or any of the interactions between or among these factors. Combining data for the two years did not show a significant difference either. On the average, there were only 84 clover plants/m^2 in 1993 but 398 clover plants in 1994.

The effect of N application on clover dry matter (DM) was highly significant and negative. Nitrogen application reduced clover DM from 6.2 g/m^2 to 2.1 g/m^2. This may be because N application favoured the growth of wheat which suppressed the growth of clovers. Weed control significantly ($P < 0.05$) increased clover DM from 2.6 g/m^2 to 5.2 g/m^2. The effects of variety, P and all the interactions on clover DM was not significant (Table 4).

3.5 Soil test

At the crops harvest, average values for soil pH, organic carbon (OC), N and K were about 4.9, 1.7%, 0.17% and 1.6 meg/100 g, respectively. None of the main effects of the five factors studied nor any of the two-factor interactions had significant effects on soil pH, soil N or soil P. Neither were the main effects of these factors significant on OC or soil K. Nevertheless, the variety x clover, N x weed control and P x weed control interactions had significant effect on soil OC. With Dashen, OC increased due to clover addition, but with ET-13 OC declined in the presence of clovers. Weed control slightly reduced OC when N or P was not applied, while it increased OC when either was applied.

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Table 4: Variety, N and P effects on clover count and above ground dry weight on Holetta red soil
Tabelle 4: Sorte, N und P Einflüsse auf Pflanzenzahl und Trockenmasse von Klee

Factor	Level	Log (Number of clover plants per 0.25 m²)			Log (biomass)
		1993	1994	Mean	
Variety	Dashen	1.317	1.977	1.647	1.386
	ET-13	1.323	2.020	1.671	1.360
N	–	1.376	1.958	1.667	1.606
	+	1.264	2.038	1.651	1.140**
P	–	1.289	2.057	1.673	1.250
	+	1.351	1.939	1.645	1.496
Weeding	–	n.a.	n.a.	n.a.	1.219
	+	n.a.	n.a.	n.a.	1.526*
Error		0.0570	0.0570	0.0403	0.0932

*; ** significant difference between the levels of a factor at 5 % and 1 %, respectively
n.a. not available

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Eingelangt am 9. März 1998
Angenommen am 18. Juli 1998