CHAPTER 2

The Influence of Soil pH on the Morphology of *Bromus pectinatus* Thunb.

ABSTRACT

Bromus pectinatus Thunb. was grown in pots, in three soils, and in three environments, as well as in one soil amended over a range of pH. Plants grown in a strongly acid soil (pH = 4.8) had fewer culms, panicles and spikelets than did plants grown in moderately acid soils (pH = 5.2 and 5.7). Plants grown outdoors matured earlier, but were shorter in height and had fewer culms, panicles and spikelets than plants grown in the glasshouse or in the shade house. An acid plinthic ferrisol soil amended to a pH of 3.37 could not support growth of *B. pectinatus*. Amended to a pH of 7.55 the acid plinthic ferrisol soil could support *B. pectinatus* but the plants took longer to mature, were shorter, and had fewer culms, panicles and spikelets than plants grown in the same soil amended to pH 5.00, 6.55 and 7.15. The optimum pH for growth of *B. pectinatus* in an amended acid plinthic ferrisol is suggested to be around 6.55 as maximum culm, panicle and spikelet numbers occurred at this pH.

INTRODUCTION

Kamprath (1984) suggests that grasses adapted to the tropics, are generally very tolerant of soil acidity. *Bromus pectinatus* Thunb. is a grass native to Kenya, and a serious weed in many wheat and barley fields in the Kenyan uplands. About 30% of the wheat growing areas of

Kenya are acid plinthic ferrisols (pH 4.3 - 5.0) and the average pH of these acid soils is 4.9 (Mulamula, 1983). The barley growing regions of Kenya, which often coincide with the wheat growing regions are reported to range in pH from 4.4 to 6.1, with an average soil pH of 5.7 (Owino *et al.*, 1983).

The acid fertilizers monoammonium phosphate (11:52:0) and diammonium phosphate (11:46:0) are commonly available in Kenya (Anonymous, 1983). Use of these fertilizers may be increasing soil acidity in the traditional wheat and barley growing areas.

Increasing land subdivision into small holdings is pressuring traditional large scale cereal producers in the Kenya highlands, to move into more marginal areas (Briggs, 1983). A general movement of cereal production to more marginal areas, including areas with more acid soil, may result in a change of weed competitors in the crops.

It has been well established that weed floras are influenced by soil pH (Buchanan *et al.*, 1975). The weediness of *B. pectinatus* may be affected by soil pH, as in other *Bromus* species. For example Behrendt and Hanf (1979) stated that *B. secalinus* L. is commonly found in winter cereals on acid soils whereas *B. tectorum* L., *B. erectus* Huds. and *B. arvensis* L. are more likely to occur on alkaline soils. *B. mollis* was difficult to establish in fields with soil pH of 4.15 to 4.3 (Mott, 1962).

It is important that it be determined whether *B. pectinatus* will continue to be a serious weed in the new marginal wheat and barley production regions. Long term projections as to Kenyas future crop yields, and input (herbicides, soil amendments) requirements can then be more accurately predicted.

The objectives of these experiments were to observe the growth of *B. pectinatus* on three Kenyan soils, and on an acid plinthic ferrisol amended to a range of pH. An experiment was also conducted using three populations of *B. pectinatus*, from Kenya, to determine if there were any differences in growth and development. Subspecies would be expected to show independent marked variation in growth form and/or internal biochemistry in response to certain aspects of their environment (Aldrich, 1984).

MATERIALS AND METHODS

Soil was collected from fields at the Agricultural Experimental Farm, Eldoret; the Kenya Breweries Ltd. Research Station, Mau Narok; and the National Plant Breeding Station, Njoro. The soil was collected from the 5 to 25 cm depth during September 1982, and placed in dry storage, in gunny bags, until used. Soil samples were sent to the National Agricultural Laboratories, Nairobi, for analysis. The results of the soil analysis are presented in Table 2.

Seed samples of *B. pectinatus* were hand stripped from mature plants growing near the Njoro soil collection site, on September 16, 1982, and near the Mau Narok soil collection site on December 1, 1982. The Eldoret soil collection site had no *B. pectinatus* present so *B. pectinatus* samples were hand stripped from mature plants on November 30, 1982, at the Kruger farm, Sergoit Rock, a site which had a soil pH of 5.4, and was located 12 km from the Eldoret soil collection site. All collected seed was air dried and stored in opaque air tight plastic containers in the laboratory.

Table 2. Description of soil types.

Site :		ELDORET	MAU NAROK	NJORO
Altitude (Metres) :		2150	2835	2165
Climate Class :		Semi-humid	Sub-humid	Semi-humid
Soil Texture : %sand/%silt/%clay :		Clay Loam 32/38/30	Loam 32/44/24	Clay Loam 36/30/34
Soil pH (H_2O, 1:1) :		4.8	5.2	5.7
Exchangeble Acidity (Hp m.e.%) :		0.6	0.3	-
Available Nutrients	Total N% :	0.18	0.43	0.24
	P "Mehlich" ppm :	18	15	12
	K m.e. % :	1.43	1.22	2.00
	Ca m.e. % :	2.8	8.0	4.4
	Na m.e. % :	0.09	0.16	0.12
	Mn m.e. % :	0.98	0.90	1.40
Organic Matter (C %) :		2.00	4.02	2.14

General Procedures

These experiments were all conducted at the National Plant Breeding Station, Njoro, under three growth environments. These environments were the out-of-doors, a shadehouse (an opaque fiberglass roofed, open sided, structure) and a glasshouse.

Soil was added to 20 cm diameter, 4 liter plastic pots, and uniformly compacted. Five seeds were placed 1 to 2 cm deep into the soil. After the seeds had emerged they were thinned to one plant per pot. Pots were observed on a daily basis and were watered as necessary to maintain healthy growth. No fertilizers or supplementary lighting was used.

At maturity (>95% of the plants senescent) the plants were evaluated for plant height (from soil surface to tip of the highest spikelet when plant held erect), number of culms, number of spikelets and number of panicles. The number of days from planting until the first panicle emerged was also recorded. The average number of spikelets per panicle is the result of dividing the spikelets per plant by the panicles per plant.

This data was analysed by ANOVA and tests for significance conducted using the least significant difference (LSD) test. Only differences found by the LSD test at the 5% significance level were considered meaningful.

Experiment 1(a). The effect of soil type and environment on growth of three sources of *Bromus pectinatus* Thunb.

Seed from each of the three seed sources was sown February 21, 1983, into each of the three soil types for a total of 9 treatments. These treatments were grown in a randomized complete block design with four replicates in the three growth environments. Plants were evaluated on July 20, 1983, when all plants were considered mature.

Experiment 1(b). The effect of soil type and environment on growth of *Bromus pectinatus* Thunb.

This experiment is similar in design to Experiment 1(a), with 4 replicates, but only the Njoro seed source was sown in the three soils. This gave a total of three treatments, instead of the nine in Experiment 1(a).

Experiment 1(b) was sown on June 29, 1983, and evaluation of mature plants grown out-of-doors and in the shadehouse were made December 1, 1983. Glasshouse grown plants were evaluated on January 24, 1984.

Experiment 2. The influence of amending an acid plinthic ferrisol on growth of *Bromus pectinatus* Thunb.

In this experiment, soil collected at Eldoret, an acid plinthic ferrisol, had its pH modified using concentrated H_2SO_4, to lower pH, and 74% $Ca(OH)_2$ powder, to raise soil pH. The amended soil was conditioned for a period of 45 days by putting the soil through alternating cycles of wetting and drying. Samples of the amended soil were taken before and after the experiment and the average pH recorded as the treatment pH. The treatment pH were 3.37, 5.00, 6.55, 7.15 and 7.56. The amended soils were then divided among the replicates and placed in pots arranged in a 5x5 latin square design in the shadehouse. The Sergoit Rock

collected *B. pectinatus* seed was sown into these pots on July 21, 1983, and evaluation of mature plants conducted on January 4, 1984.

RESULTS AND DISCUSSION

There were fewer culms, panicles and spikelets produced on *B. pectinatus* plants grown in soil from Eldoret than the plants grown on Mau Narok and Njoro soils (Tables 3, 4, 5 and 6). Plant height, days to first panicle emergence, and spikelets per panicle of plants grown in the Eldoret soil was not significantly different from plants grown in the Mau Narok and Njoro soil. It appears that in *B. pectinatus* plant height, days to first panicle emergence and spikelets per culm are less subject to variation due to edaphic factors than are culm number and panicle number.

From the description of the soil (Table 2) it is apparent that the major difference in soil properties between the soil from Eldoret and the soils from Mau Narok and Njoro is that the Eldoret soil is more strongly acid than the other two. It is difficult for plants to survive in strongly acid soils because acid soils often induce nutrient deficiencies and/or elemental toxicities (Follett *et al.*, 1981). Owino *et al.*, (1983) suggests the main reasons for difficulty in growing barley in low pH soils in Kenya are applied phosphate fixation and accumulation of aluminum and iron to phytotoxic levels.

Eldoret soil was lower in nitrogen than the other two soils. The low nitrogen may have reduced culm production in the *B. pectinatus* plants grown in this soil. Low nitrogen levels in the soil appear to

Table 3. Pot growth of three Bromus pectinatus Thunb. seed sources grown in three soils out-of-doors at the NPBS Njoro, Kenya.

SOURCE[1] SEED	SOURCE[2] SOIL	PLANT HEIGHT (cm)	DAYS TO FIRST PANICLE EMERGENCE	CULMS PER PLANT	SPIKELETS PER PLANT	PANICLES PER PLANT	SPIKELETS PER CULM
MN	MN	52.0 abc[3]	88.3 c	14.0 a	350.0 a	13.0 ab	27.0 a
N	MN	53.3 abc	89.5 c	14.5 a	347.3 a	13.0 ab	26.8 a
SR	MN	55.5 ab	89.5 c	15.3 a	347.8 a	13.0 ab	27.0 a
MN	N	60.5 a	94.8 c	11.0 b	293.8 a	11.0 b	26.5 a
N	N	58.3 a	92.3 c	13.8 a	323.0 a	13.3 a	24.5 ab
SR	N	53.3 abc	90.8 c	13.8 a	325.5 a	12,5 ab	25.8 a
MN	E	47.0 c	120.5 a	2.5 c	30.0 b	2.3 c	13.5 c
N	E	45.3 c	118.3 a	3.0 c	53.8 b	3.0 c	18.0 bc
SR	E	48.5 bc	108.3 b	3.3 c	87.0 b	3.3 c	27.0 a
AVERAGE		52.6	98.0	10.1	239.8	9.4	24.0
$LSD_{.05}$		9.2	9.8	2.5	60.6	2.1	6.7
C.V.		12	7	17	17	16	19

[1] Seed Sources : MN = KBL research station Mau Narok, N = NPBS Njoro, SR = Sergoit Rock Eldoret.

[2] Soil Sources : MN = KBL research station Mau Narok, N = NPBS Njoro, E = AEF Eldoret

[3] Numbers in the same column followed by the same letter do not differ significantly ($P \geq .05$) according to the LSD test.

Table 4. Pot growth of three Bromus pectinatus Thunb. seed sources grown in three soils in the shadehouse at the NPBS Njoro, Kenya.

SOURCE[1] SEED	SOIL[2]	PLANT HEIGHT (cm)	DAYS TO FIRST PANICLE EMERGENCE	CULMS PER PLANT	SPIKELETS PER PLANT	PANICLES PER PLANT	SPIKELETS PER CULM
MN	MN	60.5 ab[3]	93.5 c	13.5 a	324.5 b	12.8 b	25.8 abc
N	MN	59.3 ab	107.5 abc	15.5 a	370.8 ab	13.8 ab	27.3 a
SR	MN	60.8 ab	103.0 bc	15.8 a	345.3 ab	15.0 ab	23.0 bc
MN	N	67.0 a	112.3 abc	15.0 a	401.3 a	14.5 ab	28.0 a
N	N	67.8 a	100.3 c	14.8 a	371.3 ab	13.8 ab	26.8 ab
SR	N	68.3 a	102.0 bc	15.8 a	405.3 a	15.5 a	26.5 ab
MN	E	56.8 b	122.3 ab	4.5 b	79.0 c	4.3 c	18.8 d
N	E	62.5 ab	113.5 abc	4.5 b	100.0 c	4.5 c	21.8 cd
SR	E	61.5 ab	127.8 a	3.0 b	90.3 c	3.0 c	29.0 a
AVERAGE		62.7	109.1	11.8	276.4	10.8	25.2
$LSD_{.05}$		9.2	20.6	3.1	65.2	2.5	4.1
C.V.		10	13	19	16	16	11

[1]Seed Sources : MN = KBL research station Mau Narok, N = NPBS Njoro, SR = Sergoit Rock Eldoret.

[2]Soil Sources : MN = KBL research station Mau Narok, N =NPBS Njoro, E = AEF Eldoret.

[3]Numbers in the same column followed by the same letter do not differ significantly ($P \geq .05$) according to the LSD test.

Table 5. Pot growth of three Bromus pectinatus Thunb. seed sources grown in three soils in a glasshouse at the NPBS Njoro, Kenya.

SOURCE[1] SEED	SOIL[2]	PLANT HEIGHT (cm)	DAYS TO FIRST PANICLE EMERGENCE	CULMS PER PLANT	SPIKELETS PER PLANT	PANICLES PER PLANT	SPIKELETS PER CULM
MN	MN	76.0 b[3]	117.0 bc	14.5 abc	372.0 ab	13.5 bc	28.3 c
N	MN	77.3 b	117.0 bc	16.3 ab	407.3 ab	14.3 abc	28.5 c
SR	MN	79.0 ab	111.8 c	17.3 a	430.8 a	16.0 a	27.3 c
MN	N	80.3 a	125.5 bc	15.5 abc	388.3 ab	14.5 ab	26.8 c
N	N	76.3 b	122.0 bc	12.8 c	354.5 b	12.3 bc	29.3 bc
SR	N	74.8 b	118.5 bc	13.3 bc	352.5 b	12.0 c	29.8 bc
MN	E	75.8 b	127.0 b	4.0 d	133.0 c	3.3 d	36.5 abc
N	E	87.8 a	144.5 a	4.0 d	153.3 c	4.0 d	39.5 ab
SR	E	77.5 b	123.5 bc	5.0 d	168.5 c	4.3 d	43.8 a
AVERAGE		78.3	123.0	11.4	306.7	10.5	32.2
$LSD_{.05}$		9.0	14.2	3.0	70.9	2.3	10.8
C.V.		8	8	18	16	15	23

[1]Seed Sources : MN = KBL research station Mau Narok, N = NPBS Njoro, SR = Sergoit Rock Eldoret.

[2]Soil Sources : MN = KBL research station Mau Narok, N = NPBS Njoro, E = AEF Eldoret

[3]Numbers in the same column followed by the same letter do not differ significantly ($P \geq .05$) according to the LSD test.

Table 6. Pot growth of Njoro source Bromus pectinatus Thunb. grown in three soils in three environments.

ENVIRONMENT[1]	SOIL SOURCE[2]	PLANT HEIGHT (cm)	DAYS TO FIRST PANICLE EMERGENCE	CULMS PER PLANT	SPIKELETS PER PLANT	PANICLES PER PLANT	SPIKELETS PER CULM
O	MN	93.0 e[3]	63.5 d	14.3 b	300.0 c	13.3 bc	23.0 bcd
O	N	94.7 de	61.0 d	16.8 ab	367.0 bc	18.3 a	20.3 cd
O	E	55.7 f	78.3 c	2.5 c	20.0 d	1.5 d	12.5 d
S	MN	109.3 bc	75.3 c	19.3 ab	610.5 a	17.8 ab	43.8 a
S	N	102.0 cd	74.5 c	18.8 ab	493.0 ab	18.5 a	34.0 ab
S	E	92.7 e	76.8 c	5.5 c	84.3 d	4.8 d	15.5 cd
G	MN	113.7 b	123.0 a	16.8 b	312.8 c	12.5 c	25.3 bc
G	N	109.0 bc	107.8 b	22.5 a	338.5 bc	14.5 abc	24.0 bcd
G	E	123.0 a	113.8 b	5.3 c	138.0 d	4.3 d	34.5 ab
AVERAGE		99.3	86.0	13.8	296.0	11.7	25.9
$LSD_{.05}$		8.9	8.7	5.3	156.7	4.6	11.6
C.V.		8.0	6.8	25.9	35.6	26.2	2.5

[1] Environments : O =out-of-doors, S = shadehouse, G = glasshouse

[2] Soil Sources : MN = KBL research station Mau Narok, N = NPBS Njoro, E = AEF Eldoret

[3] Numbers in the same column followed by the same letter do not differ significantly ($P \geq .05$) according to the LSD test.

minimize the phytotoxic effect of soil acidity. High rates of N can replace Al^{+} from the soil exchange sites and increase the phytotoxicity of an acid soil (Kamproth, 1984).

Out-of-doors grown *B. pectinatus* plants consistantly had the shortest plants, the least number of culms, panicles and spikelets per panicle relative to plants grown in the shadehouse or glasshouse (Tables 3, 4, 5 and 6). Out-of-doors grown plants generally began panicle emergence earlier than did shadehouse or greenhouse grown plants. Glasshouse grown plants, in general, took the longest to mature, were the tallest, and often had the most spikelets per plant.

At an altitude of 2500 m the average Kenyan wheat variety takes 130 days to mature and the average Kenyan barley variety 149 days to mature (Anonymous, 1984). It took the *B. pectinatus* grown in these experiments from 61 (Table 6) to 145 days (Table 5) for the first panicles to emerge, with the overall average being 104 days. Thus, the majority of the *B. pectinatus* plants have panicles which emerge well before the crop has matured.

There were no significant trends observed in relation to seed source. *B. pectinatus* seed origin (Mau Narok, Njoro or Sergoit Rock) had no influence on plant height, first panicle emergence, culms per plant, spikelets per plant, panicles per plant, or spikelets per culm (Tables 3, 4 and 5). There was much more variation within the seed populations, than between the seed populations, despite having been grown in many different environmental combinations. This lack of variation in seeds from different sites implies that the three seed sources are one species and that none of these three were a distinct subspecies of *B. pectinatus*. Subspecies would vary markedly in growth

form and/or internal biochemistry (Aldrich, 1984). The possibility that there may be a subspecies of *B. pectinatus* on an internal biochemistry basis was not investigated in these experiments.

Experiment 1(a) and 1(b) were conducted on soils which ranged in pH from 4.8 to 5.7. On these soils, soil pH influenced the number of culms, panicles and spikelets per plant. Experiment 2 was conducted on soils of a broader pH range, from 3.37 to 7.56. Over the broader pH range, plant height, days to panicle emergence, and the number of spikelets per culm were also affected (Figure 3).

The acid plinthic ferrisol soil from Eldoret, amended to pH 3.37 did not allow germination or growth of *B. pectinatus* (Figure 3). Even *B. pectinatus* seedlings transplanted, in the one to two leaf stage, into the pots with this soil, did not survive.

B. pectinatus plants, grown in pots containing the acid plinthic ferrisol amended to pH 7.56, was shorter (Figure 3A), had fewer culms (Figure 3C), fewer panicles (Figure 3E), fewer spikelets (Figure 3D and 3F) and took longer to mature (Figure 3B), than any of the other surviving treatments. Optimum growth of *B. pectinatus* occurred when the acid plinthic ferrisol was amended to pH 6.55. At the pH of 6.55, number of culms, spikelets and panicles were the highest of all the treatments, whereas, plant heights, days to first panicle emergence and spikelets per culm were not different from the other surviving acid soil treatments. Despite the best weedy growth of *B. pectinatus* at a pH of 6.55 this pH should not be considered the optimum for all soils.

Buchanan *et al.* (1975) demonstrated that it is not possible to define critical soil pH values for any plant species except for a particular soil. Soil fertility, soil organic matter and amount of

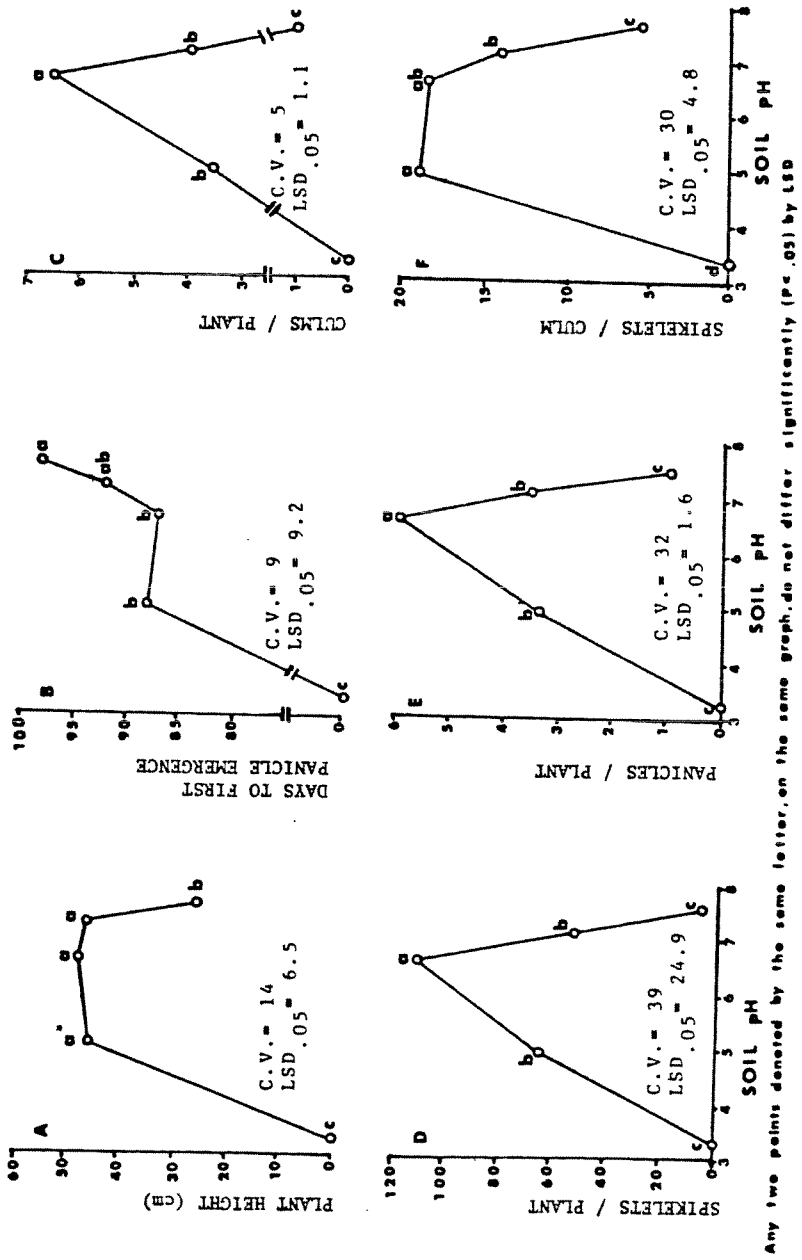

Figure 3. The influence of soil pH on Bromus pectinatus Thunb. plant height (A), days to first panicle emergence (B), culms per plant (C), spikelets per plant (D), panicles per plant (E), spikelets per culm (F).

competition can influence plant response to soil pH. High rates of nitrogen and potassium can replace aluminum from the soil and increase the phytotoxicity of an acid soil (Kamprath, 1984). Increasing the level of soil organic matter will allow plants to be more tolerant of soil acidity (Follett *et al.*, 1981). Competition can shift the optimum pH for growth of some species (Barbour *et al.*, 1980). In Experiment 2 the plants were grown in pots under no competition.

Kamprath (1984) suggests that in acid tropical soils primary consideration must be given to removing the soil acidity factors limiting growth, rather than liming to increase soil pH. Use of acid fertilizers, such as DAP and MAP, may actually help to reduce the weediness of *B. pectinatus*, by increasing soil acidity which can be antagonistic to *B. pectinatus*.

At slightly alkaline pH (pH 7.56) the growth of *B. pectinatus* was inhibited (Figure 3). With liming materials readily available in Kenya (Mulamula, 1983) it might be possible to lime slightly acid soils to a slightly alkaline pH which may reduce the competitiveness of *B. pectinatus* against crops growing in this soil.

Soil pH does have an effect on weediness of *B. pectinatus*, but whether this effect can be used as a control measure has yet to be determined. Potential difficulties with modifying soil pH include the cost of the soil amendments, the time required to achieve change, and changes in persistance and efficacy of soil applied herbicides (Walker and Buchanan, 1982).