COMPETITION BETWEEN ANNUAL WEEDS (WILD MUSTARD, WILD BUCKWHEAT) AND SPRING SOWN SMALL GRAINS (OATS AND BARLEY) WHEN GROWN IN THE GREENHOUSE

Thesis for the Degree of M. S.

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William Ming-Chuan Liu

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This is to certify that the

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COMPETITION BETWEEN ANNUAL WEEDS
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AND SPRING SOWN SMALL GRAINS
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WHEN GROWN IN THE GREENHOUSE

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By

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Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

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INTRODUCTION

Competition between crop plants and weeds is a most fundamental factor in the growing of useful plants. If crop plants occupy the soil and are vigorous, weeds are excluded or retarded in their growth. On the other hand, if the crop stand is thin or lacks vigor, weeds will flourish. Any environmental condition or any procedure that promotes the growth of crop plants tends to diminish the ill effects of weeds. Conversely, conditions or methods unfavorable to the growth of useful plants permit the invasion and development of a weed population.

Competition is usually evident in cultivated fields. Individual crop plants may compete with each other, or they may compete with weeds. The keenest competition, as between weeds and crop plants, usually occurs when the individuals competing are most alike in their vegetative habits, methods of reproduction, and demands upon the environment.

The chief environmental factors in plant competition are water, light, and mineral nutrients, their importance usually being in the order given. There is no conclusive

evidence that root secretions are a factor in plant competition. Two plants do not compete if water, light, and mineral nutrients are in excess of the needs of both. Competition begins when the supply of any one of these factors falls below the requirements of both. Thus, if there is an abundance of nutrients and water, light may be the critical factor; or there may be a sufficiency of water and light for the two neighboring plants but a deficiency of nutrients, in which instance the latter becomes the critical factor in competition; or competition may be for water only, in the event that nutrients and light are ample.

This experiment was designed with the purpose of studying the effects on the yield of Kent Oats and Moore barley when in competition with two different weeds at different rates of seeding. The two weeds used were wild mustard (Brassica arvensis) and wild buckwheat (Polygonum convolvulus). The former has proved to be very competitive in recent experiments carried out in the greenhouse, and both were found very common in the spring sown small grain fields.

REVIEW OF LITERATURE

Blackman and Templeman (3) have published a fundamental study of competition between cereal crops and annual weeds in England. Crop development data on barley and oats competing with Brassica arvensis and Raphanus raphanistrum indicate that nitrogen is an important factor in competition. The presence of weeds had a greater depressing effect on cereal yield in wet than in dry springs because the establishment of the weed seedlings and their later growth were adversely affected by a dry spring.

Pavlychenko and Harrington (15) studied competition between crops and various species of weeds. They ranked the crops in order of competing ability as follows: barley, rye, wheat, oats, and flax. Among the weeds, Avena fatua and Brassica arvensis were the most vigorous competitors.

Brenchley (4) explained that one of the chief factors in determining the abundance or scarcity of a particular weed is the degree of competition it is able to withstand successfully, and furthermore, the above-ground struggle for light is as important as the underground struggle for food and water.

According to Clements, Weaver and Hanson (6), the problem of competition in field crops "is centered upon the relative merits of species and varieties in terms of competitive adaptation to seasonal and annual cycles and to the tillage and rotation control of factors and reactions." Each weed and species of crop has its own merits of competitive adaption and its own reactions toward its rivals.

The effects of competition were noted in forest communities by De Crescentiuis (9), in the plant kingdom generally by De Candolle (8), and in nature as a whole by Charles Darwin (7).

Nägeli (14), 1874, suggested that the probable number of individuals of a competing species in a given habitat is determined by the average life period and average annual increase.

Montgomery (13) studied the competitive abilities of cereal crops. He found, for instance, that Turkey Red wheat is much stronger competitor than Big Frame wheat. He states that a small admixture of the former in a sample of the latter increased rapidly and in a few years produced ninety percent of the total stand.

Kiesselbach (12) found that the yield of plants of a given variety fluctuated within broad limits as a result of differences in spacing or surrounding growth. Aaltonen (1) emphasized the importance of the underground parts of field crops in competitive reactions.

Sukatschew (17) showed that some biotypes which are vigorous competitors in open cultures do poorly in dense ones.

Cates (5) estimated that weeds reduce the yield of spring grain twelve to fifteen percent.

Hopkins (11) and Barnes and Hopkins (2) have shown by experiments carried on over a period of years at the Dominion Experiment Station, Swift Current, Saskatchewan, that the yield of wheat may be reduced as much as fifty percent as a result of competition with weeds.

The depressing effect some annual weeds have on grain yield in Canada was reported by Godel (10). He states that annual weeds can be economically controlled in cereal crops in Northern districts of Saskatchewan, by proper rates of seeding of the cereals. He suggests the following rates:

Barley - 2-2.5 bushels per acre
Oats - 2.5-3 bushels per acre

The exact rate within those limits will depend on the variety sown, the condition of the land at seeding, the size of grain kernels, and the degree of weed infestation of fields.

Robinson (16) studied determination of the effect of annual weeds on certain environmental factors and on yields of crops. In some cases crops with moderate infestations of annual weeds yielded less than crops grown under weed-free conditions, but this was not always true.

MATERIALS AND METHODS

This experiment was conducted in the greenhouse at Michigan State College, East Lansing, Michigan, beginning in December, 1950. Two annual weeds, wild mustard (Brassica arvensis) and wild buckwheat (Polygonum convolvulus), and two spring sown small grains, Kent Oats and Moore Barley, were used for study. Each of the weeds and grains was seeded alone as checks at six and twelve seeds per pot. Then each weed was seeded at six and twelve seeds per pot with grain at the same two rates. Thus there were twenty-four possible combinations of treatments. They are:

Oats 6 alone
Oats 12 alone
Barley 6 alone
Barley 12 alone

W. Mustard 6 alone
W. Mustard 12 alone
W. Buckwheat 6 alone
W. Buckwheat 12 alone

Oats 6 - W. Mustard 6
Oats 6 - W. Mustard 12
Oats 12 - W. Mustard 6
Oats 12 - W. Mustard 12

Barley 6 - W. Mustard 6
Barley 6 - W. Mustard 12
Barley 12 - W. Mustard 6
Barley 12 - W. Mustard 12

Oats 6 - W. Buckwheat 6
Oats 6 - W. Buckwheat 12
Oats 12 - W. Buckwheat 6
Oats 12 - W. Buckwheat 12

Barley 6 - W. Buckwheat 6
Barley 6 - W. Buckwheat 12
Barley 12 - W. Buckwheat 6
Barley 12 - W. Buckwheat 12

The above treatments were replicated four times, making a total of 96 pots.

The seed was sown in 10-inch clay pots on December 19 and 20, 1950, using quartz sand as the medium. At six plants per pot the seeding should be approximately equal to 1.104 bushels for oats and 0.736 bushel for barley per acre. The weeds seeded at six plants and twelve plants per pot were considered as light and heavy infestation respectively.

Since the grain seeds and weed seeds vary so much in percentage germination, a germination test was made for each grain and weed to determine the number of seeds to be sown per pot. In accordance with the germination test, a reasonable amount of seeds of each species were seeded. The extra plants were thinned out later to give the proper stand.

The depth of planting for the grains was 1-1/2 inches and for the weeds, 1/2 inch.

After sowing, the cultures were watered regularly and supplied with a nutrient solution to secure the best growth under winter and spring greenhouse conditions. The nutrient solution was fed once a week beginning ten days after the small grains started to germinate. The amount was five hundred cubic

centimeters for each pot until February 23. Then later on, it was fed twice a week to March 16, and reduced to once a week again until the end of this experiment.

In the first two months the temperature in the greenhouse was about 70° F. in daytime and 55° F. at night. After March the temperature was gradually increased to 80° to 90° F. in daytime and 70° F. at night.

The pots were randomized on the bench in the greenhouse. A rearrangement of the pots was made on February 28, 1951, to move the center pots to the side and vice versa. On March 5 the space between pots was expanded on the bench in order to give enough room for each pot.

The barley and oats were germinated four days after sowing, wild mustard three days, and wild buckwheat seven days. On January 3, oats and barley were thinned to eight and fourteen plants per pot for the stand of six and twelve. On January 26 they were thinned again to the exact number. The wild mustard was thinned on January 18 and some transplanting of seedlings was made for pots having an insufficient number of seedlings. The wild buckwheat grew slower than the others and

was thinned on January 24. All pots were staked with wire on January 29 and 30.

The wild mustard started to bloom on February 23 and continued until the end of this experiment. Oats and barley began to head on March 2, but barley headed more uniformly later. The wild buckwheat began to flower on March 6, but finished flowering before the end of this experiment.

The entire experiment lasted for 108 days until April 6, 1951. The barley was harvested at fully headed stage while the oats ranged from late boot to fully headed stage. The plants were harvested by cutting one-half inch above the surface of the sand. The number of the plants and heads of each pot was counted. Grain plants and weed plants were weighed separately, both green weight and oven-dried weight being recorded.

RESULTS AND DISCUSSION

In considering the competition between small grains and weeds of this experiment, the factors studied have been: (1) the effect of competition of weeds upon the number of heads of small grain per plant, (2) effect upon the total yield of dry weight of small grain per plant and per pot, and (3) effect upon the moisture content of small grain.

Effect on Number of Heads per Plant

Table I shows the effect of rates of seeding and wild mustard upon the number of heads of oats and barley per plant. When oats and barley were grown at the rate of six plants alone, the number of heads per plant was highest. Increasing the rate to twelve plants greatly reduced the number of heads per plant of both oats and barley. This might be explained by the competition within the species itself.

The comparison of the effect of wild mustard on heads of oats and barley per plant is shown in Figure 1.

Adding six additional oat plants to the light rate of seeding decreased the number of heads per plant more than

TABLE I. Effect of rates of seeding of oats, barley, and wild mustard upon number of heads of oats and barley per plant.

Rates and Mixtures	Heads Per Plant	
	Oats	Barley
6 plants oats alone	1.63	
6 plants barley alone		2.29
12 plants oats alone	1.08	
12 plants barley alone		1.23
6 plants oats + 6 plants wild mustard	1.17	
6 plants oats + 12 plants wild mustard	1.17	
12 plants oats + 6 plants wild mustard	1.04	
12 plants oats + 12 plants wild mustard	1.04	
6 plants barley + 6 plants wild mustard		1.71
6 plants barley + 12 plants wild mustard		1.92
12 plants barley + 6 plants wild mustard		1.47
12 plants barley + 12 plants wild mustard		1.02

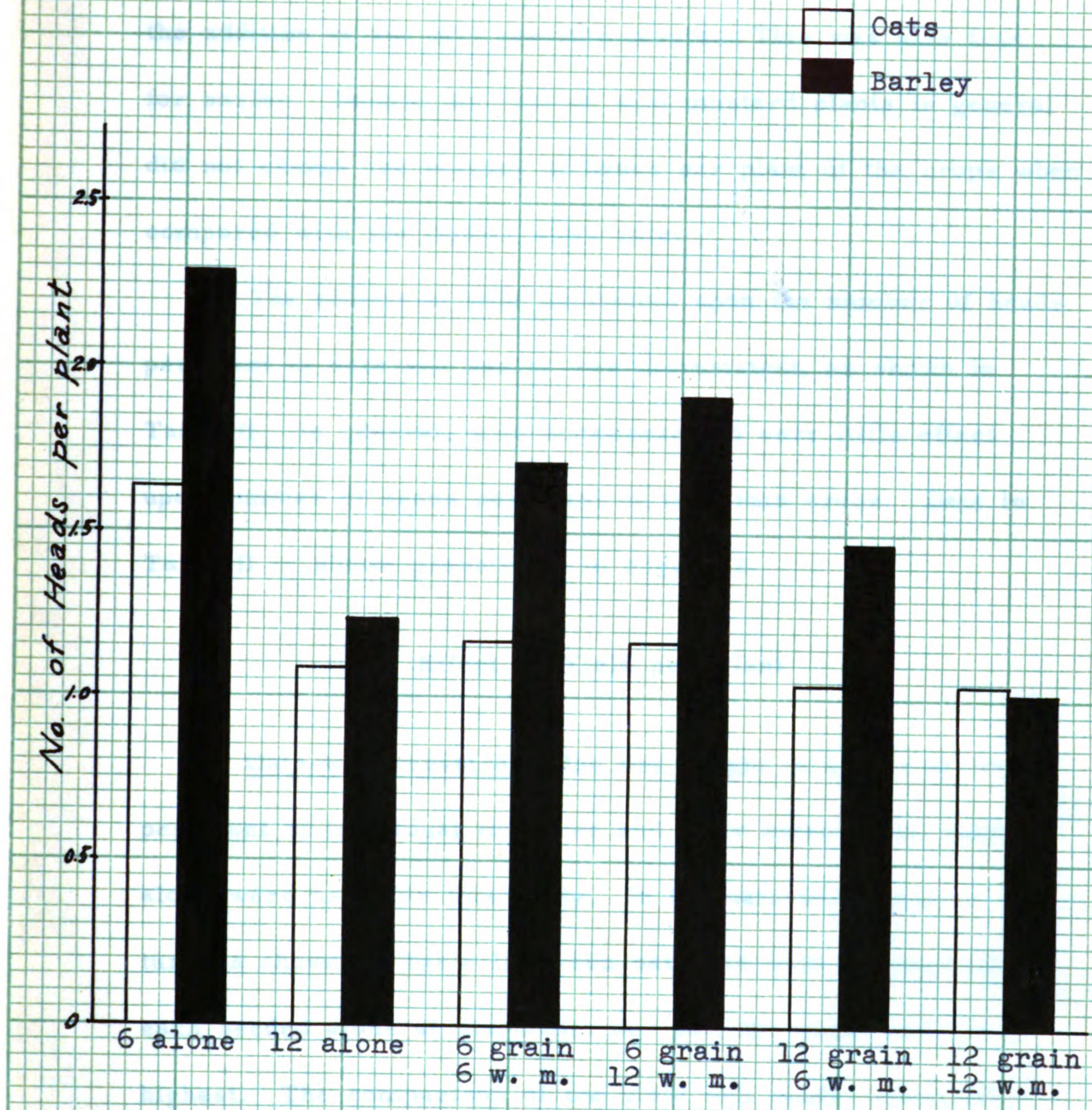

Figure 1. Comparison between the number of heads of oats and barley per plant by the effect of wild mustard at different rates of seeding.

the addition of six wild mustard plants. This was also true for barley. Double the rate of wild mustard plants in general did not change the number of heads per plant of the crops when compared with the lighter weed rate.

The effects of wild buckwheat upon the number of heads per plant of oats and barley was inconsistent, as shown in Table II. In general, wild buckwheat had very little effect upon number of heads per plant of the grain crops. Data in Table II is shown graphically in Figure 2.

Effect on Yield per Plant

Oats-wild mustard. The dry weight in grams of tops per plant of individual mixtures and their components seeded alone were used for this study. In the oats-wild mustard mixture as shown in Table III, when oats and wild mustard were each seeded alone at six plants per pot, the yield was the highest. The comparison of the yield was made, taking the yield of six plants alone as one hundred percent. The table indicates that when oats and wild mustard were seeded at twelve plants alone, the yield of both was greatly reduced. It was also shown that the competition within species of oats

TABLE II. Effect of rates of seeding of oats, barley, and wild buckwheat upon number of heads of oats and barley per plant.

Rates and Mixtures	Heads Per Plant	
	Oats	Barley
6 plants oats alone	1.63	
6 plants barley alone		2.29
12 plants oats alone	1.08	
12 plants barley alone		1.23
6 plants oats + 6 plants wild buckwheat	1.25	
6 plants oats + 12 plants wild buckwheat	1.58	
12 plants oats + 6 plants wild buckwheat	1.10	
12 plants oats + 12 plants wild buckwheat	1.19	
6 plants barley + 6 plants wild buckwheat		2.50
6 plants barley + 12 plants wild buckwheat		1.83
12 plants barley + 6 plants wild buckwheat		1.19
12 plants barley + 12 plants wild buckwheat		1.19

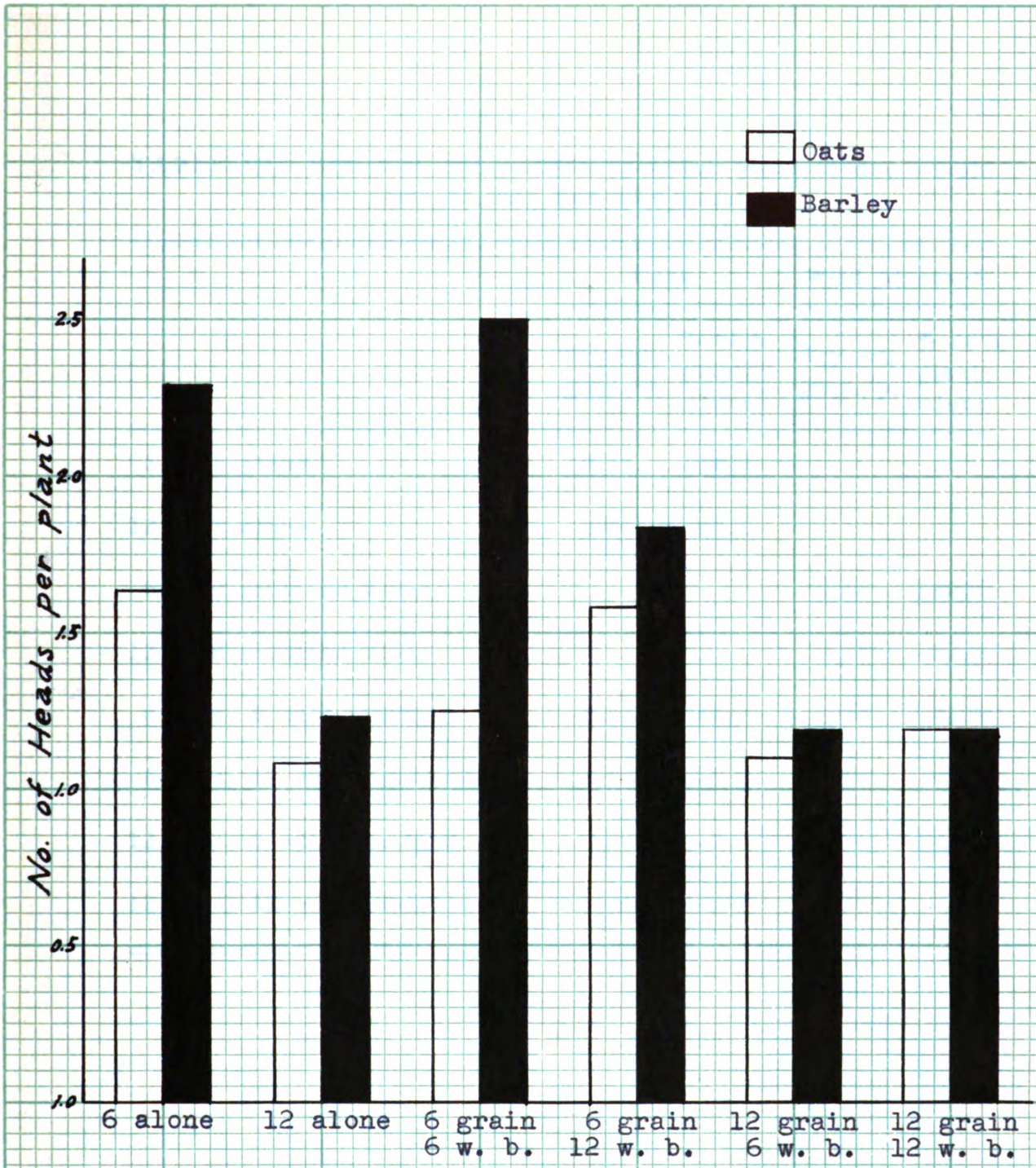

Figure 2. Comparison between the number of heads of oats and barley per plant by the effect of wild buckwheat at different rates of seeding.

TABLE III. Effect of competition upon the yield of dry weight per plant of oats and wild mustard.

	Oats		Wild Mustard	
	dry wt. gms./p.	% of 6 plants alone	dry wt. gms./p.	% of 6 plants alone
6 oats alone	8.11	100.0		
12 oats alone	4.07	50.2		
6 wild mustard alone			5.88	100.0
12 wild mustard alone			3.67	62.4
6 oats, 6 wild mustard	5.23	64.6	2.52	42.9
6 oats, 12 wild mustard	4.94	60.9	1.81	30.8
12 oats, 6 wild mustard	3.49	43.0	1.23	20.9
12 oats, 12 wild mustard	3.46	42.7	0.58	9.9

itself was greater than when infested by wild mustard. Where oats were infested by wild mustard, the heavier the rate of wild mustard used, the more the reduction in the yield of oats.

Wild mustard reduced the weight per plant less in the heavy than in the light rate of oat seeding. The dry weight per plant of wild mustard was reduced more by the addition of oats than by the addition of more wild mustard. The yield of wild mustard was suppressed by the oats of different rates of seeding. Figure 3 shows the effect of competition upon the yield of dry weight per plant of oats and wild mustard.

Oats-wild buckwheat. The results with wild buckwheat as shown in Table IV were more or less the same as that of oats-wild mustard mixture.

It is evident from Tables III and IV that oats suppressed the yield per plant of wild buckwheat more than it did wild mustard. Figure 4 gives a general trend toward the yield of dry weight per plant of oats and wild buckwheat as well as their effect on each other.

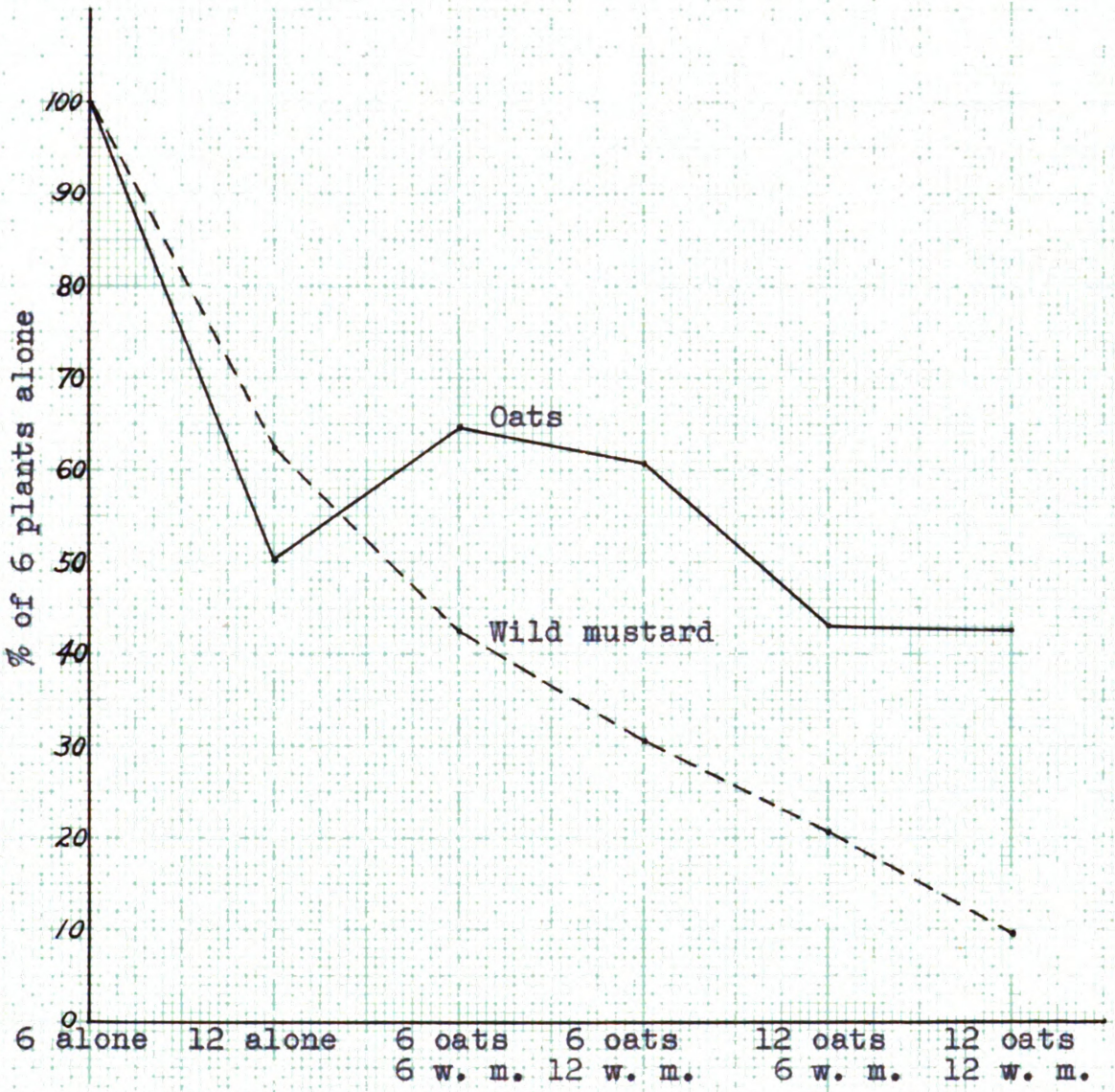

Figure 3. Effect of competition upon the yield of dry weight per plant of oats and wild mustard.

TABLE IV. Effect of competition upon the yield dry weight per plant of oats and wild buckwheat.

	Oats		Wild buckwheat	
	dry wt. gms./p.	% of 6 plants alone	dry wt. gms./p.	% of 6 plants alone
6 oats alone	8.11	100.0		
12 oats alone	4.07	50.2		
6 wild buckwheat alone			3.13	100.0
12 wild buckwheat alone			1.61	51.4
6 oats, 6 wild buckwheat	7.12	87.8	0.23	7.4
6 oats, 12 wild buckwheat	7.24	89.3	0.28	9.0
12 oats, 6 wild buckwheat	4.07	50.2	0.21	6.7
12 oats, 12 wild buckwheat	4.29	52.9	0.18	5.8

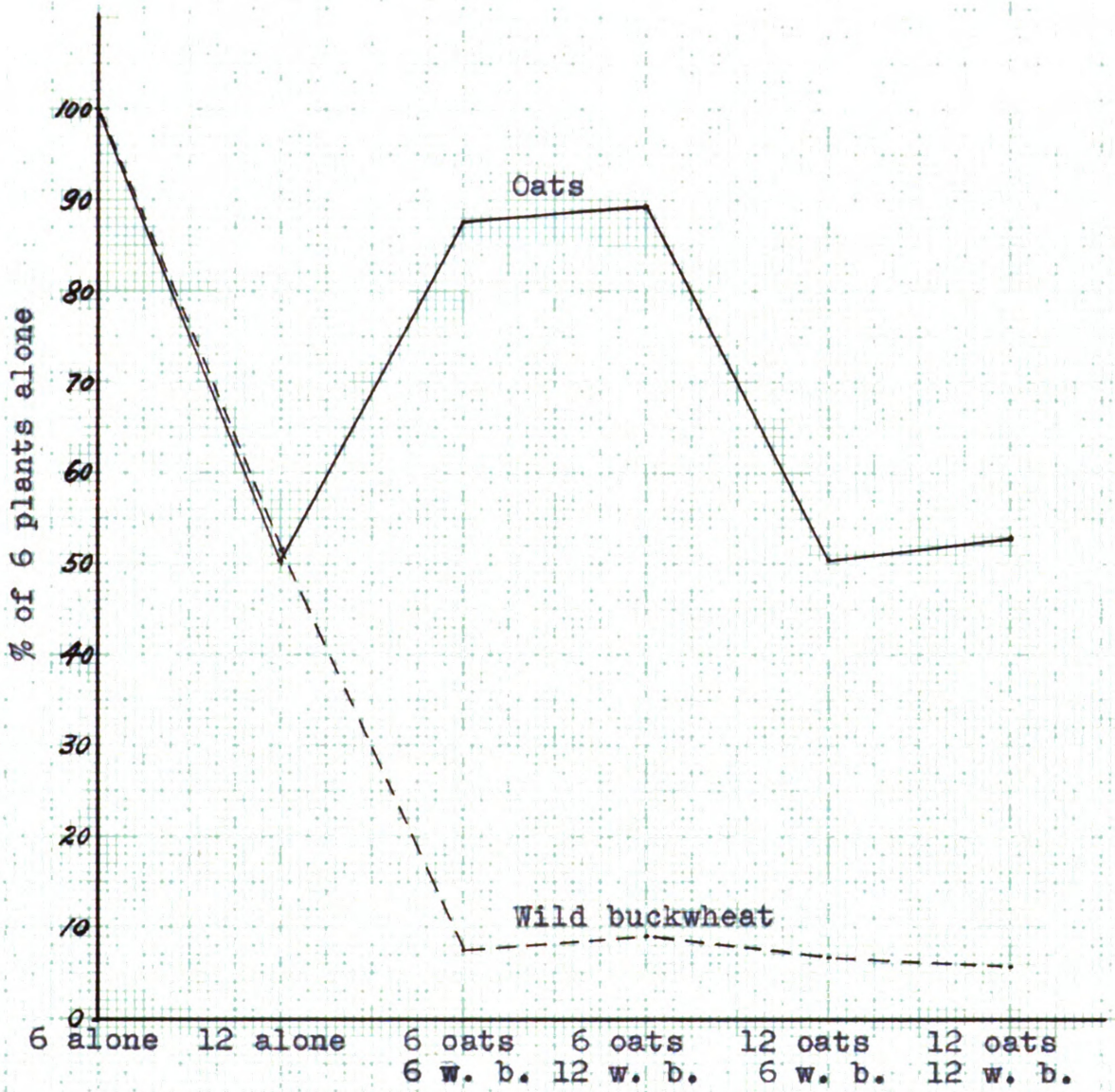

Figure 4. Effect of competition upon the yield of dry weight per plant of oats and wild buckwheat.

Barley-wild mustard. Table V shows that the yield per plant of barley was affected more by barley itself than by wild mustard. Wild mustard had less effect on the yield per plant of 12 barley than it did on 6 barley. Increasing the rate of seeding of wild mustard, according to the data, tends to decrease the yield per plant of barley. It should be noted, however, that the yield of 12 barley when in mixture with 6 wild mustard was slightly higher than when 12 barley was grown alone.

A considerable reduction in the yield of wild mustard due to the effect of barley has been observed, the more barley in the mixture, the more was the suppressive effect; the effect being even greater than that due to wild mustard itself.

Figure 5 shows the effect of various mixtures on the yield of dry weight per plant of barley and wild mustard.

Barley-wild buckwheat. Table VI reveals that the yield of wild buckwheat per plant was reduced very much by barley. Wild buckwheat, on the other hand, exerted less effect on the yield of barley than barley did itself. These results in general agree with the barley-wild mustard mixtures.

TABLE V. Effect of competition upon the yield dry weight per plant of barley and wild mustard.

	Barley		Wild Mustard	
	dry wt. gms./p.	% of 6 plants alone	dry wt. gms./p.	% of 6 plants alone
6 barley alone	7.97	100.0		
12 barley alone	4.31	54.1		
6 wild mustard alone			5.88	100.0
12 wild mustard alone			3.67	62.4
6 barley, 6 wild mustard	6.89	86.5	1.39	23.6
6 barley, 12 wild mustard	6.02	75.5	0.98	16.7
12 barley, 6 wild mustard	4.58	57.5	0.70	11.9
12 barley, 12 wild mustard	3.44	43.2	0.43	7.3

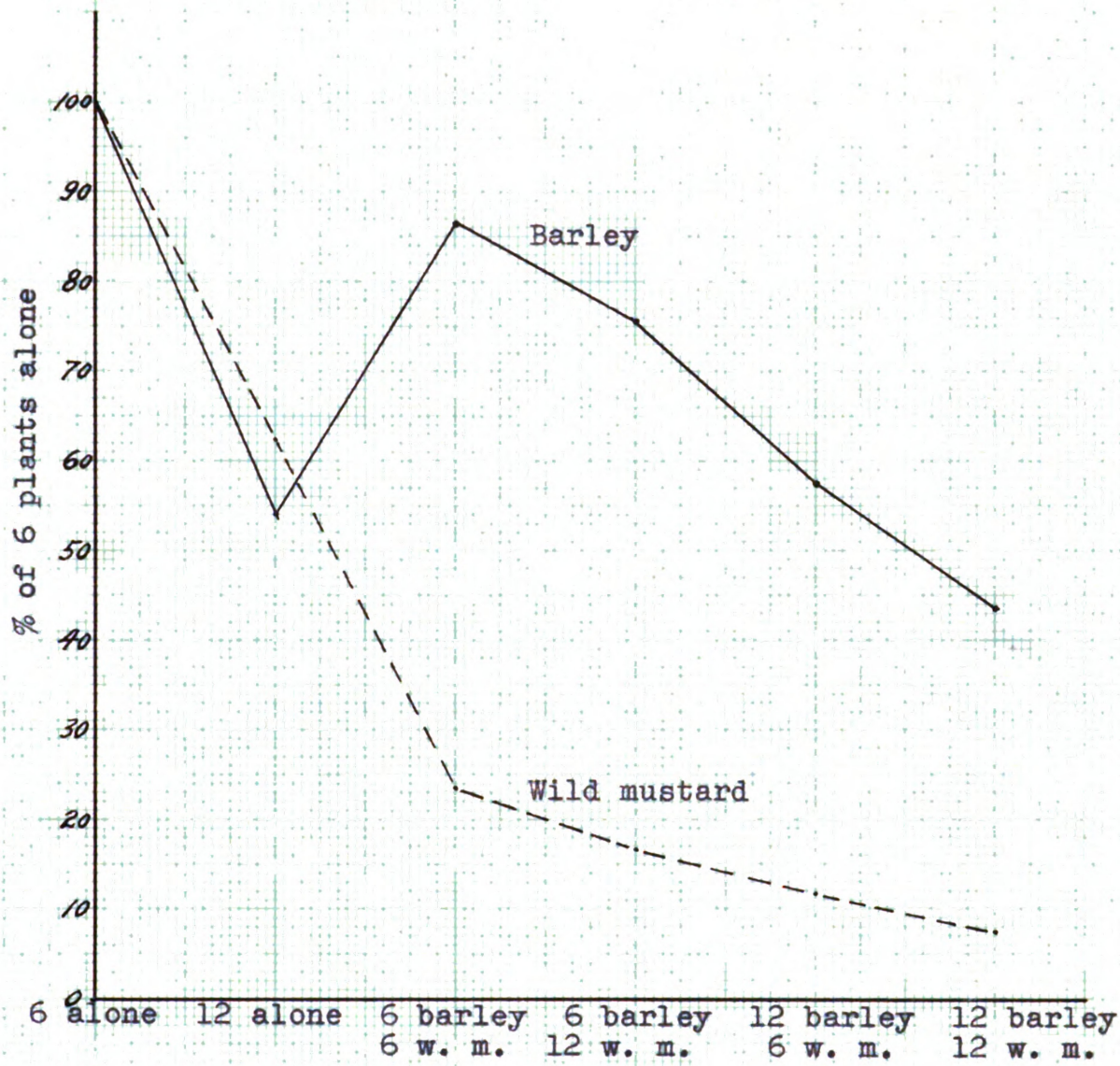

Figure 5. Effect of competition upon the yield of dry weight per plant of barley and wild mustard.

TABLE VI. Effect of competition upon the yield dry weight per plant of barley and wild buckwheat.

	Barley		Wild Buckwheat	
	dry wt. gms./p.	% of 6 plants alone	dry wt. gms./p.	% of 6 plants alone
6 barley alone	7.97	100.0		
12 barley alone	4.31	54.1		
6 wild buckwheat alone			3.13	100.0
12 wild buckwheat alone			1.61	51.4
6 barley, 6 wild buckwheat	8.26	103.6	0.31	4.2
6 barley, 12 wild buckwheat	6.59	82.7	0.09	2.9
12 barley, 6 wild buckwheat	3.81	47.8	0.09	2.9
12 barley, 12 wild buckwheat	3.97	49.8	0.08	2.6

It will be noted from data in Tables III, IV, V, and VI that barley was a stronger competitor than oats and that wild mustard was a stronger competitor than wild buckwheat. The grain crops were stronger competitors than the weeds.

The yield of dry weight per plant of barley-wild buckwheat mixture is shown in Figure 6.

Effect on Total Yield per Pot

Total yield of small grain per pot is shown in Table VII.

The total dry weight of oats per pot was essentially the same for the six-plant and twelve-plant rates. The twelve-plant rate of barley exceeded the six-plant rate by approximately eight percent (Fig. 7).

Adding six wild mustard or six wild buckwheat to the light rate of seeding of either oats or barley decreased the total yield of small grain per pot much more than the addition of six weeds to the heavy rate of grain seeding.

Wild mustard decreased grain yields more than wild buckwheat.

Wild buckwheat had an adverse effect on oats yield when the latter was planted at the higher rate. Yields of barley

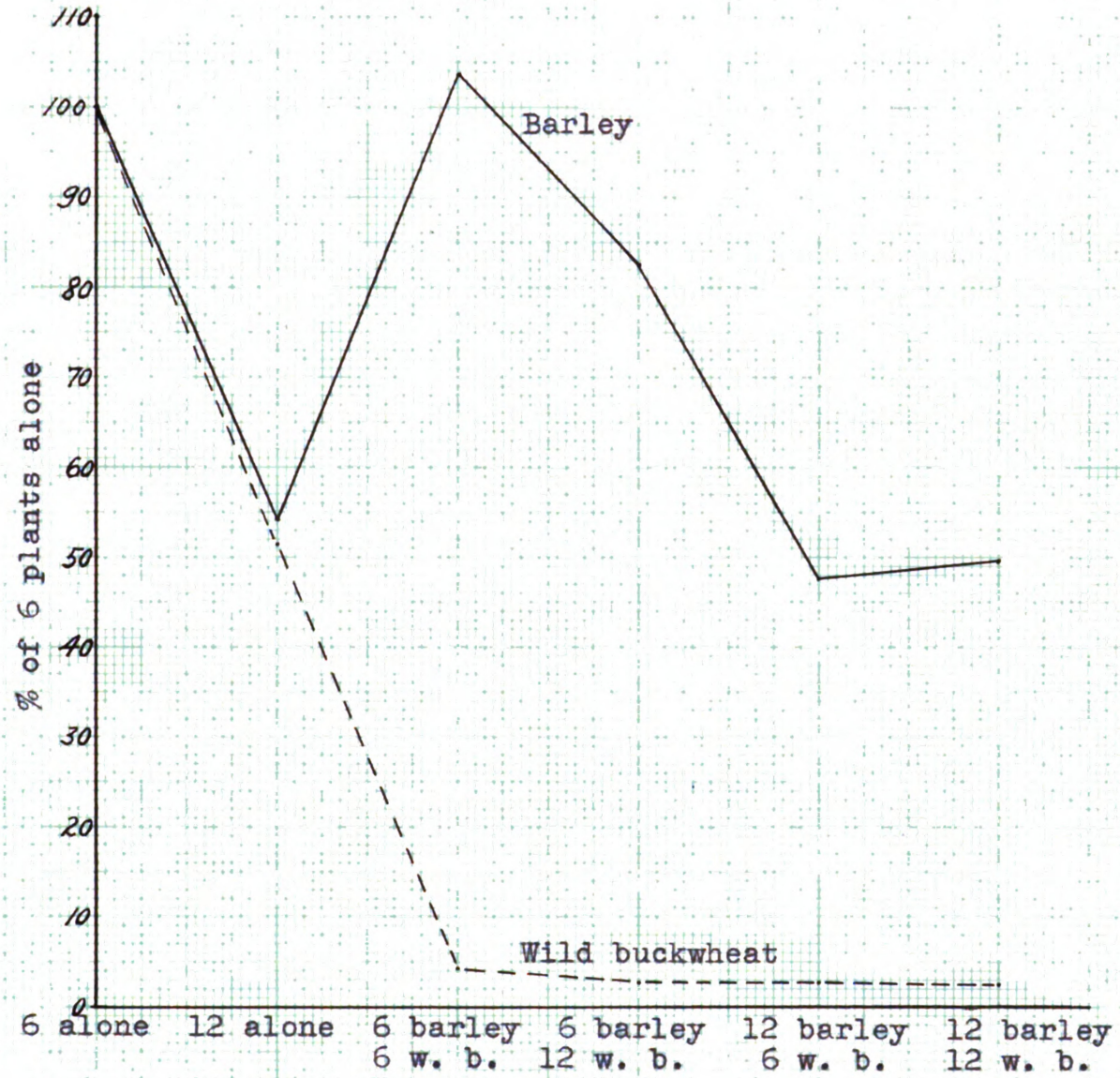

Figure 6. Effect of competition upon the yield of dry weight per plant of barley and wild buckwheat.

TABLE VII. Effect of competition upon the total dry weight per pot of small grain in different rates of seeding when in mixture with weeds.

	Yield of total dry wt. (Gms./Pot)	
	Oats	Barley
6 crop alone	48.66	47.82
12 crop alone	48.84	51.72
6 crop, 6 w. mustard	31.38	41.89
6 crop, 12 w. mustard	29.64	36.12
12 crop, 6 w. mustard	41.88	44.96
12 crop, 12 w. mustard	41.52	44.28
6 crop, 6 w. buckwheat	42.72	43.56
6 crop, 12 w. buckwheat	43.44	44.54
12 crop, 6 w. buckwheat	48.84	45.72
12 crop, 12 w. buckwheat	51.48	47.64

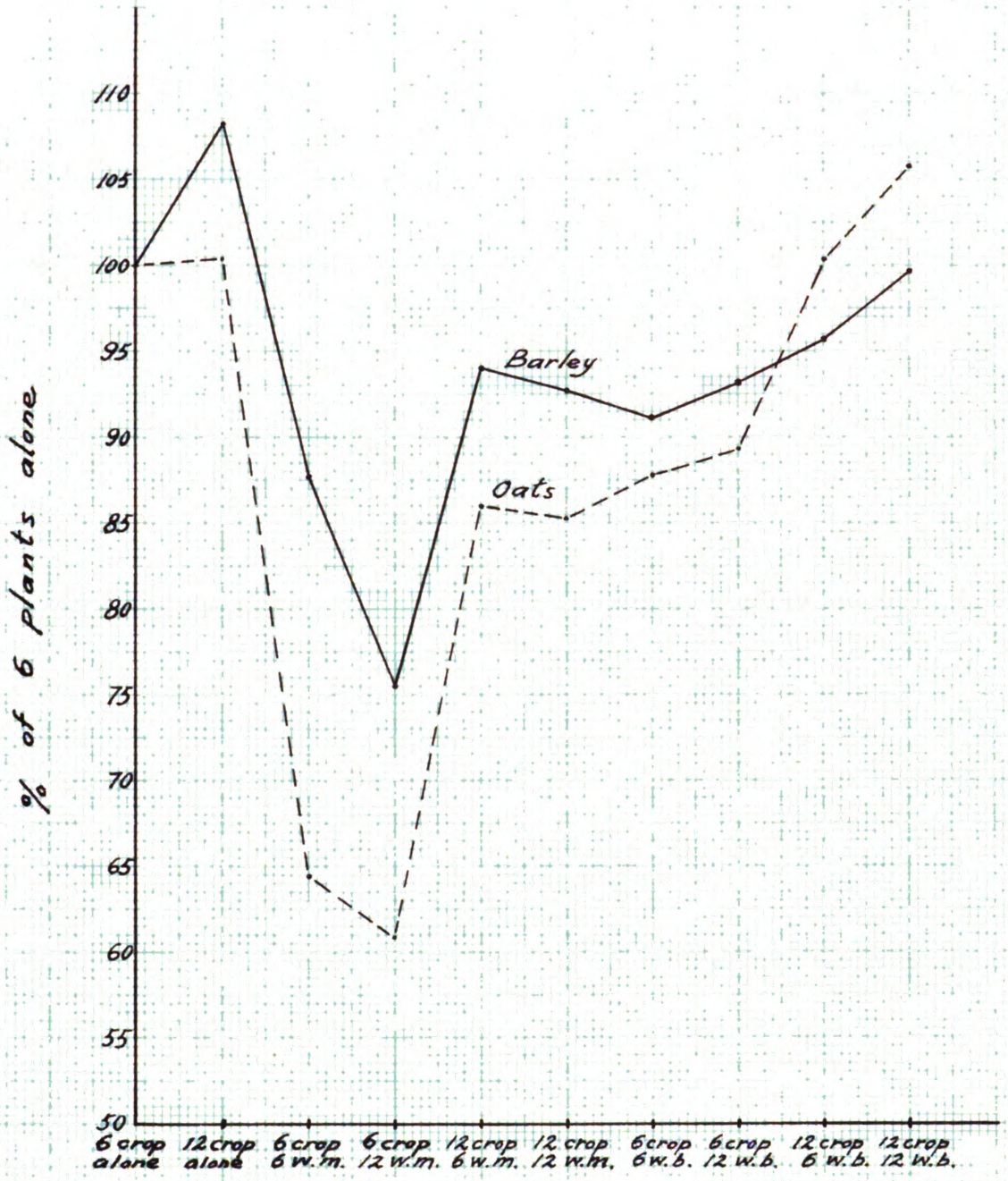

Figure 7. Effect of competition upon the total yield of dry weight per pot of small grain in different rates of seeding when in mixture with weeds.

from the higher rate were reduced slightly by the addition of wild buckwheat.

Barley had more resistance to the weeds than oats.

Figure 7 shows yield of each rate and mixture expressed in terms of percentage of the lighter rate of planting.

Effect on Percentage of Moisture

A study was made of the moisture content of oats and barley at different rates of seeding and in mixture with weeds. Both crops and weeds were harvested at the same time, although among them they did not show uniformity in degree of maturity. Tables VIII and IX show that the crops with heavy rate of seeding contained less percentage of moisture per plant. The percentage of moisture of oats and barley in light rates of seeding was decreased by the infestation of wild mustard as compared with the grains grown alone, which resulted in hastening the maturity of the crops.

The percentage of moisture of wild mustard was not affected when in mixture with oats; but in the presence of barley the percentage of moisture was increased, which resulted in delayed maturity of the wild mustard.

TABLE VIII. The percentage of moisture content per plant of oats, barley, and wild mustard in different rates of seeding.

	Percentage of Moisture per Plant	
	Grain	Weed
Oats 6 alone	81.03	
Oats 12 alone	76.64	
Barley 6 alone	77.73	
Barley 12 alone	74.15	
W. mustard 6 alone		80.86
W. mustard 12 alone		81.25
Oats 6, w. mustard 6	79.21	80.60
Oats 6, w. mustard 12	77.69	80.13
Oats 12, w. mustard 6	80.74	80.66
Oats 12, w. mustard 12	78.15	80.73
Barley 6, w. mustard 6	75.18	80.88
Barley 6, w. mustard 12	76.39	82.65
Barley 12, w. mustard 6	75.77	85.07
Barley 12, w. mustard 12	74.02	83.71

TABLE IX. The percentage of moisture content per plant of oats, barley and wild buckwheat in different rates of seeding.

	Percentage of Moisture per Plant	
	Grain	Weed
Oats 6 alone	81.03	
Oats 12 alone	76.64	
Barley 6 alone	77.73	
Barley 12 alone	74.15	
W. buckwheat 6 alone		78.84
W. buckwheat 12 alone		77.36
Oats 6, w. buckwheat 6	80.73	71.95
Oats 6, w. buckwheat 12	78.37	75.65
Oats 12, w. buckwheat 6	77.69	69.12
Oats 12, w. buckwheat 12	78.07	75.00
Barley 6, w. buckwheat 6	78.05	72.34
Barley 6, w. buckwheat 12	77.12	81.25
Barley 12, w. buckwheat 6	77.00	77.50
Barley 12, w. buckwheat 12	74.87	72.41

Wild buckwheat had little effect on the percentage of moisture of either oats or barley. Oats in this experiment tended to decrease the percentage of moisture of wild buckwheat, resulting in earlier maturity. The effect of barley upon the maturity of wild buckwheat was variable.

SUMMARY

Oats, barley, wild mustard, and wild buckwheat were grown in the greenhouse at different rates of seeding for studying the competition between small grain and weeds.

1. The effects of competition upon the number of heads and dry weight per plant within the species of small grain itself were greater than by weeds.

2. Wild mustard had more effect on the number of heads and dry weight per plant of small grain than wild buckwheat.

3. The rates of infestation of weeds in general did not change the number of heads per plant of the small grain.

4. Weeds had less effect on the yield of dry weight per plant in the heavier rate of seeding of small grain than in the lighter rate.

5. The heavier infestation of wild mustard caused more reduction of the yield of dry weight per plant of small grain.

6. The total yield of dry weight per pot of small grain was not decreased by increasing the seeding rates, but by the infestation of weeds.

7. The higher rate of seeding of barley increased the total yield of dry weight per pot about eight percent.

8. Wild mustard decreased crop yields more than wild buckwheat.

9. Barley had more resistance to the weeds than oats.

10. The moisture content per plant of small grain grown alone was decreased by increasing the seeding rate.

11. Wild mustard caused earlier maturity of small grain with light seeding rate.

12. Wild mustard was delayed in maturity by the presence of barley and wild buckwheat was hastened to maturity by the presence of oats.

13. The competing ability among these four plants ranked as follows: barley, oats, wild mustard and wild buckwheat.

BIBLIOGRAPHY

1. Aaltonen, V. T.
Ueber die räumliche Ordnung der Pflanzen auf dem Felde und im Walde.
Act. For. Fenn. 23: 7-85, 1923.

2. Barnes, S., and Hopkins, S. E.
Soil Moisture and Crop Production.
Dom. Dept. of Agric. Bull. 130 N. S. 27-30, 1930.

3. Blackman, G. E., and Templeman, W. G.
The Nature of the Competition between Cereal Crops and Annual Weeds.
Jour. Agr. Sci., 28: 247-271, 1938.

4. Brenchley, W. F.
Weeds on Farm Lands.
London: Longmans, Green Co. 1920. (Pages 159-174.)

5. Cates, H. F.
The Weed Problem in American Agriculture.
U. S. Dept. Agr. Yearbook. 1917.

6. Clements, F. E., Weaver, J. E., and Hanson, H. C.
Plant Competition.
Carnegie Inst. Wash. 1929.

7. Darwin, C.
The Origin of Species. London, 1859.
The Variation of Animals and Plants under Domestication.
2nd Ed. New York, 1876.

8. De Candolle, A. P.
Essaie élémentaire de Géographie Botanigue.
26-28. 1920.

9. De Crescentüs, Petrus.
Handschrift. 1305.

10. Godel, G. L.
Relation between Rate of seeding and Yield of Cereal Crops in Competition with Weeds.
Sci. Agr., 16: 165-168, 1935.

11. Hopkins, E. S.
Report of the Dominion Field Husbandman, Ottawa 37. 1926; 34-35. 1927; 43-46. 1928; 57-59. 1929; 43-44. 1930.

12. Kiesselbach, T. A.
Studies Concerning the Elimination of Experimental Error in Competitive Crop Tests.
Neb. Agr. Exp. Sta. Res. Bull. 13. 1918.

13. Montgomery, E. G.
Competition in Cereals.
Neb. Agr. Exp. Sta. Bull. 113. 1912.

14. Nägeli, C. 1874.
Verdrängung der Pflanzenformen durch ihre Mitbewerber.
Sitzb. Akad. Wiss. München, 11: 109-164.
Bot. Mitt. 3: 205-260. 1881.

15. Pavlychenko, T. K., and Harrington, J. B.
Competitive Efficiency of Weeds and Cereal Crops.
Can. Jour. Res., 10: 77-94. 1934.

16. Robinson, R. G.
Annual Weeds, Their Viable Seed Population in the Soil, and Their Effect on Yields of Oats, Wheat, and Flax.
Jour. Amer. Soc. Agron. 41: 513-518. 1949.

17. Sukatschew, W.
Einige experimentelle Untersuchungen über den Kampf ums Dasein zwischen Biotypen derselben Art.
Zeits. Indukt. Abs. Vererb. 47: 54-74. 1927.