

THE GROWTH ANALYSIS OF ROUND-LEAVED MALLOW
(MALVA PUSILLA Sm.)

A Thesis

Submitted to the Faculty
of
Graduate Studies

The University of Manitoba

by

Melodie Faith Budzinsky

In Partial Fulfillment of the
Requirements for the Degree

of

Master of Science
Department of Plant Science

1987 ©

Permission has been granted to the National Library of Canada to microfilm this thesis and to lend or sell copies of the film.

The author (copyright owner) has reserved other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without his/her written permission.

L'autorisation a été accordée à la Bibliothèque nationale du Canada de microfilmer cette thèse et de prêter ou de vendre des exemplaires du film.

L'auteur (titulaire du droit d'auteur) se réserve les autres droits de publication; ni la thèse ni de longs extraits de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation écrite.

ISBN 0-315-37370-9

THE GROWTH ANALYSIS OF ROUND-LEAVED MALLOW

(Malva Pusilla Sm.)

BY

MELODIE FAITH BUDZINSKY

A thesis submitted to the Faculty of Graduate Studies of
the University of Manitoba in partial fulfillment of the requirements
of the degree of

MASTER OF SCIENCE

© 1987

Permission has been granted to the LIBRARY OF THE UNIVERSITY OF MANITOBA to lend or sell copies of this thesis, to the NATIONAL LIBRARY OF CANADA to microfilm this thesis and to lend or sell copies of the film, and UNIVERSITY MICROFILMS to publish an abstract of this thesis.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

Acknowledgments

I would like to express my gratitude to Dr. I.N. Morrison for his supervision and preparation of this thesis. I am also grateful to the members of my advisory committee; Dr. S. Edie and Dr. G. Robinson for their helpful suggestions on putting this manuscript together. I would like to thank Dr. G. Marshall for his initiation of this project. Thanks are due to the graduate students and technical staff of the Weed Science Laboratory for their assistance and friendliness at Portage and in the Lab; Tannis, Ken, Doug and Saw. I would also like to thank; Dr. B. Todd, Mr. R. Cristoff, Mr. E. Matthys, and Mr. J. Webber for their assistance at Manitou. I am also grateful to Miss. R. Mucousky and Dr. K. Mortenson, for their assistance in gathering information for this paper.

Special thanks are due to my family, Mom, Dad, Donna and Charlene who came with me to Manitou and Portage and worked late nights with me in the lab, weekdays and weekends.

Table of Contents

	page
List of Tables.....	vi
List of Figures.....	vii
Abstract.....	x
Introduction.....	1
1. Review of Literature.....	3
1.1 Taxonomy.....	3
1.2 Biology.....	5
1.2.1 Morphology.....	5
1.2.2 Growth and Development.....	6
1.2.3 Sexual Reproduction and Seed Dormancy.....	7
1.3 Ecology.....	9
1.3.1 Distribution and Habitat.....	9
1.3.2 Competition of Weeds with Crop Species....	15
1.3.3 Growth Analysis.....	21
1.3.4 Economic Importance.....	25
1.4 Chemical Cultural and Biological Control.....	27
1.4.1 Chemical Control.....	27
1.4.2 Cultural Control.....	31
1.4.3 Biological Control.....	31
2. Materials and Methods.....	33
2.1 Pot Experiments.....	33

	page
2.2 Field Experiments.....	37
2.2.1 Field Growth Analysis (1985).....	37
2.2.2 Field Growth Analysis (1986).....	40
2.3 Germination Studies.....	46
3. Results.....	47
3.1 Pot Experiments (1985 and 1986).....	47
3.2 Field Experiment	55
3.2.1 1985.....	55
3.2.1.1 Crop Establishment.....	55
3.2.1.2 Growth Analysis.....	59
3.2.1.3 Crop Yield.....	70
3.2.2 1986.....	72
3.2.2.1 Crop Establishment.....	72
3.2.2.2 Growth Analysis.....	73
3.2.2.3 Crop Yield.....	83
3.3 Germination Studies.....	83
4. Discussion.....	86
4.1 Growth Analysis.....	86
4.2 Control of Mallow.....	96
4.3 Competition Results.....	98
4.4 Germination Studies.....	100
Bibliography.....	102

	page
Appendices.....	107
Municipality of Pembina.....	107
Climatological Data.....	109
Pot Grown Mallow Data.....	116
Raw Field Data (Mallow, 1985).....	119
Raw Field Data (Mallow, 1986).....	124

List of Tables

Table	page
I. Regional distribution of mallow in Manitoba.....	I0
2. Occurrence of mallow in the Altona and Carmen district.....	I2
3. Occurrence of mallow in Manitoba fields.....	I3
4. Occurrence of mallow in Saskatchewan fields.....	I4
5. Competition of mallow in Crops.....	I6
6. Mathematical growth analysis formulae.....	38
7. Growth analysis of mallow in pots grown outdoors (I985/I986) ..	49
8. Density, growth stage and dry weight of mallow, sprayed and unsprayed, at Manitou, Manitoba (I985).....	6I
9. Growth analysis of mallow, sprayed and unsprayed, in a flax field at Manitou, Manitoba (I985).....	68
I0. Growth analysis of mallow, sprayed and unsprayed, in a wheat field at Manitou, Manitoba (I985).....	69
II. Yield of Flax and Wheat (I985).....	7I
I2. Density, growth stage and dry weight of mallow, sprayed and unsprayed, in field trials at Portage la Prairie Research Station, Manitoba (I986).....	76
I3. Growth analysis of mallow, sprayed and unsprayed, in flax field trials at Portage la Prairie Research Station, Manitoba (I986).....	80
I4. Growth analysis of mallow, sprayed and unsprayed, in wheat field trials at Portage la Prairie Research Station, Manitoba (I986).....	82
I5. Yield of flax and wheat (I986).....	84
I6. Germination of mallow seed.....	85

List of Figures

Figure	page
I. Growth habit of round-leaved mallow.....	4
2. Maximum, minimum and mean temperatures and precipitation for the I985 growing season in Winnipeg, Manitoba.....	35
3. Maximum, minimum and mean temperatures and precipitation for the I986 growing season in Winnipeg, Manitoba.....	35
4. Degree days for the I985 and I986 growing season in Winnipeg, Manitoba.....	36
5. Maximum, minimum and mean temperatures and precipitation for the I985 growing season in Manitou, Manitoba.....	41
6. Degree days for the I985 growing season in Manitou, Manitoba.....	42
7. Maximum, minimum and mean temperatures and precipitation for the I986 growing season at the Portage la Prairie Research Station, Manitoba.....	44
8. Degree days for the I986 growing season at the Portage la Prairie Research Station, Manitoba.....	45
9. (a) Pattern of dry matter distribution in pot grown mallow in I985.....	48
(b) Pattern of dry matter distribution in pot grown mallow in I986.....	48
I0. (a) Leaf area of mallow grown in pots (I985).....	51
I0. (b) Leaf area of mallow grown in pots (I986).....	51
II. (a) IAR of mallow grown in pots (I985).....	52
II. (b) IAR of mallow grown in pots (I986).....	52
I2. RGR of mallow grown in pots (I985).....	53
I3. RGR of mallow grown in pots (I986).....	54

Figure	page
I4. Leaf area-Dry weight accumulation of mallow 1985.....	56
I5. Leaf area-Dry weight accumulation of mallow 1986.....	56
I6. (a) NAR of mallow grown in pots (1985).....	57
I6. (b) NAR of mallow grown in pots (1986).....	57
I7. (a) Density of flax plants in a field infested with mallow at Manitou, Manitoba.....	58
I7. (b) Dry weight of flax plants in a field infested with mallow at Manitou, Manitoba.....	58
I8. (a) Density of wheat plants in a field infested with mallow at Manitou, Manitoba.....	60
I8. (b) Dry weight of wheat plants in a field infested with mallow at Manitou, Manitoba.....	60
I9. RGR of mallow growing in a flax field at Manitou, Manitoba(1985).....	62
20. RGR of mallow in a wheat field at Manitou, Manitoba.....	63
2I. (a) IAR of mallow growing in a flax field at Manitou, Manitoba.....	65
2I (b) IAR of mallow growing in a wheat field at Manitou, Manitoba.....	65
22. (a) NAR of mallow grwoing in a flax field at Manitou, Manitoba.....	66
22. (b) NAR of mallow growing in a wheat field at Manitou, Manitoba.....	66
23. (a) Density of flax plants in a field trial infested with mallow (Portage la Prairie, 1986).....	74
23. (b) Dry weight of flax plants in a field trial infested with mallow (Portage la Prairie, 1986).....	74
24. (a) Density of wheat plants in a field trial infested with mallow (Portage la Prairie, 1986).....	75

Figure	page
24. (b) Dry weight of wheat plants in a field trial infested with mallow (Portage la Prairie, 1986).....	75
25. RGR of mallow growing in flax field trials at the Portage la Prairie Research Station, Manitoba.....	77
26. RGR of mallow growing in wheat field trials at the Portage la Prairie Research Station, Manitoba.....	78
27. (a) IAR of mallow growing in flax field trials at the Portage la Prairie Research Station.....	79
27. (b) IAR of mallow growing in wheat field trials at the Portage la Prairie Research Station.....	79

ABSTRACT

Budzinsky, M.F., M.Sc., The University of Manitoba, 1987.
The Growth Analysis of Round-leaved Mallow (Malva pusilla Sm.). Major Professor: Dr. I.N. Morrison, Department of Plant Science.

The growth of round-leaved mallow (Malva pusilla Sm.) was studied under noncompetitive and competitive conditions in 1985 and 1986. The data obtained provided indications of the high degree of plasticity of mallow. Initially mallow was characterized by the accumulation of biomass toward photosynthetic apparatus as indicated by the high initial SLA of $618 \text{ cm}^2 \text{ g}^{-1}$ and LAR of $463 \text{ cm}^2 \text{ g}^{-1}$. The NAR remained approximately $0.01 \text{ g cm}^{-2} \text{ week}^{-1}$ through the sampling period.

The RGR for each plant part followed an integrated pattern of growth, both in competitive and non-competitive situations. The maximum RGR for leaves in the absence of competition exceeded $2.0 \text{ g g}^{-1} \text{ week}^{-1}$. This high RGR has been reported to be indicative of a highly competitive weed.

Following the application of bromoxynil (3,5-Dibromo-4-hydroxybenzonitrile) at 0.28 kg ha^{-1} and MCPA {[(4-Chloro-o-tolyl) oxy] acetic acid} at 0.28 kg ha^{-1} the RGR decreased for all plant parts. The herbicide killed the apical meristem which initiated the growth of lateral buds. The RGR increased, thus, although the leaves were killed by the herbicide the stems were not affected. This increase shows

the recuperative ability of mallow.

Mallow decreased the yield of flax 97% and wheat 21% due to the aggressive competition provided. Flax plants in weedy plots attained a height comparable to those in weed-free plots, however, stooling was inhibited by the competition.

Introduction

Malva pusilla Sm. (round-leaved mallow) is an annual or biennial weed which occurs in many parts of the world. This weed was introduced from Europe to North America, and although it is primarily a weed of farmyards and waste places, it has been encroaching into cropland.

Mature M. pusilla plants exhibit a prostrate growth habit with cylindrical stems and petioles. The petioles terminate in leaves which are crenate with a cordate base (Jaques, 1959). The flowers of M. pusilla are extremely small, borne in the axils of the petioles. M. pusilla is characterized by having a well-developed tap root.

In Manitoba, the main distribution of M. pusilla is in the southern, central and eastern regions. M. pusilla has been reported to grow in flax, wheat and barley fields (Thomas and Wise, 1982). Survey results indicate that the relative abundance of M. pusilla increased from 1979 to 1981 (Thomas and Wise, 1982). It has been reported (Todd, personal communication) that M. pusilla has encroached into agricultural fields and caused significant decreases in yields of flax and wheat. Since information on the competition, growth and development of M. pusilla is lacking, these studies were conducted. The main objectives were:

(1) to study the growth of various plant organs using growth analysis parameters in competitive and non-competitive situations,

(2) to examine competition with wheat and flax,

(3) to examine the efficacy of herbicide activity using growth analysis techniques,

(4) to characterize seed germination over an extended period of time.

1. Literature Review

1.1 Taxonomy

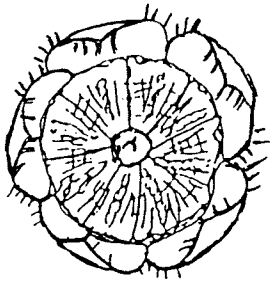
The genus Malva of the Malvaceae family has several species distributed world wide. There are three species of Malva which grow in Manitoba, these being Malva neglecta Wallr., M. parviflora L. and M. pusilla Sm. (rotundifolia L.) (Looman and Best, 1979).

Common mallow, M. neglecta, has kidney shaped leaves and the fruit consists of 12-15 smooth carpels. Small flowered mallow, M. parviflora, has flowers which are inconspicuous and nearly stalkless. The lower portions of the petals of round-leaved mallow, (M. pusilla) (Figure 1) have hairy margins, a characteristic unique to this species. Small flowered mallow has fruits which consist of 8-11 carpels arranged in a circle with the calyx reflexed at maturity. Also in this species net venation occurs on the backs of the carpels. Round-leaved mallow has fruits which consist of 12-15 smooth carpels arranged with the calyx incurved at maturity, a trait which distinguishes it from small flowered mallow. Primarily on the basis of these characteristics the three species can be distinguished.

In addition to be being called round-leaved mallow, M. pusilla has also been referred to as dwarf mallow in studies conducted in the United States (Anonymous 1981, Carlson and Eberlein 1983). Henceforth, M. pusilla will be referred to,

Figure 1. Growth habit of round-leaved mallow

- (a) Mature fruit of mallow x 10
- (b) Carpel with seed enclosed x 4
- (c) Seed x 5
- (d) Seedling x 1
- (e) Mature plant x $\frac{1}{4}$



(a)



(b)



(c)



(d)



(e)

as mallow throughout this thesis, unless there is reason to distinguish it from the other above-mentioned species.

1.2 Biology

1.2.1 Morphology

Mallow is an annual, or biennial plant which reproduces only by seed. This weed exhibits a prostrate habit of growth under noncompetitive situations with the stems radiating from the crown (Georgia 1933, Anonymous 1950, Robins, Bellue and Ball 1951, Jaques 1959). When growing in competitive situations mallow tends to be more erect (Hunter 1985, personal observation).

Mallow is characterized by having a well-developed tap root, with lateral roots radiating outwards from the crown (Byrne 1973, Byrne and Heimsch 1970). The deep branching roots of this plant spread nearly as far beneath the soil as its creeping stems spread above-ground (Georgia 1933).

The petioles terminate in leaves which are crenate with cordate bases (Jaques, 1959). The leaves of mallow are alternate, one per node and borne on long cylindrical petioles. The leaves are usually 1 to 3 inches in diameter (Jaques, 1959).

The flowers are small and occur inconspicuously in the axils. Flowers are usually in groups of 2 to 6 and borne on individual pedicles (Jaques 1959). The petals of the

flowers are white to pale lilac. There are five fused sepals, and five notched petals. Mallow flowers possess many stamens and have twelve to fifteen carpels each possessing one seed (Jaques, 1959). On the Prairies mallow plants flower from May until November.

The seeds of mallow are formed in capsules, each containing twelve to fifteen segments (Georgia 1933, Anonymous 1950, Robins et. al. 1951, Jaques 1959). Seeds of mallow are somewhat velvety and roughened, and are nearly circular with a notch in one side. The seeds are dark grey and consist of an outer row of rather thick-walled cells (Pammel 1913, Anonymous 1950). Fruits are arranged in a circle within a cup made by the calyx bracts. The embryo is tightly enclosed within the seed coat, which is loosely surrounded by the indehiscent carpel wall (Sumner and Cobb, 1967).

1.2.2 Growth and Development

Mallow requires warm conditions to germinate and for this reason seedlings generally emerge in the late spring, after most crops are seeded (Hunter, 1985a). Mallow appears to be very cold hardy and continues to produce seed late into the fall in the Prairie Provinces. Flower production usually occurs approximately four weeks after the plants germinate. In the Soviet Union, the vegetative growth period of mallow was reported to be approximately 125 days (Pyasyatskene,

1978). The most rapid growth period was during late July.

Carlson and Eberlein (1983) studied the growth and development of mallow sown in pure stands or with wheat. Seeds of mallow were acid-scarified, broadcast by hand and incorporated with a garden rake. Height, dry weight, leaf number and area were determined on a weekly basis by harvesting ten plants per plot (0.3 m² plots). It was reported that the pure stands of mallow sown at different times of the summer developed at similar rates. The yield of mallow was decreased by the wheat and no flowers were produced if mallow was sown in June or July. Regrowth of mallow occurred in the wheat stubble after harvest.

1.2.3 Sexual Reproduction and Seed Dormancy

As the seeds of mallow mature they turn from a light brown-grey to black colour. Seventy five percent of the light brown seeds germinated while only 25% of the darker seeds germinated (Hunter, 1985b). It has been suggested that as the seed matures the seed coat becomes impervious to water and germination decreases. Hunter (1985b) noted that after scarification there was 100% germination of the dark seeds. Due to the dormancy of mallow, emergence of the weed continues over a considerable period of time.

In Beal's seed viability study conducted at Michigan State University, mallow seeds germinated and produced

viable seedlings after a 100 year period of dormancy (Kivilaan and Bandurski, 1981). Seeds were stored in a soil mixture since 1879. Every fifth year for 35 years and every tenth year thereafter seeds were removed from the soil and placed under favourable conditions to record the germination rates. The percent of mallow seed which germinated after 100 years was 2%. This may seem low but it is unusual that no germination occurred since 1899, and one viable seedling was produced after 100 years.

No reports of the mechanism of dormancy of round-leaved mallow have been reported but studies have been carried out on small flowered mallow, which conceivably could be similar to round-leaved mallow. Round-leaved mallow is quite similar to small flowered mallow except that the fruit of the former consists of 12-15 carpels, while that of the latter has 8-11 carpels. At maturity the calyx of round-leaved mallow is incurved, while small flowered mallow possesses a calyx which is reflexed at maturity (Looman and Best, 1979). It has been reported that the seeds of small flowered mallow possess mechanisms to delay germination (Sumner and Cobb, 1967). Permeability of the seed coat to water does not ensure germination will occur. It is believed that the germination of the seeds is largely controlled by endogenous inhibitory substances. Endogenous inhibitors may repress germination even after the seed coat has become permeable. Thus, prolonged leaching may be necessary to remove the inhibitory compounds.

The dormancy mechanism of small flowered mallow involves a number of factors. Initially seed coat impermeability may function to increase the longevity of the seed (Sumner and Cobb, 1967), thus enabling continual germination of seeds throughout the growing season. Sumner and Cobb (1967) also noted that removal of, or rupturing the seed coat allowed for 79% germination, a substantial increase over untreated seeds. Mechanical scarification increased the percent germination.

1.3 Ecology

1.3.1 Distribution and Habitat

The relative abundance of mallow in Manitoba increased between 1978 and 1981. The relative abundance indicates the abundance of each weed species in the province or district relative to each other, and is a combination of the frequency and density. The relative abundance was used as a means of ranking species in the survey. In 1978 and 1979 the overall abundance ratings were 0.9 and 0.7, respectively, and the weed ranked as the 33rd most abundant species; while in 1981 the relative abundance was 1.6 (Thomas and Wise, 1982). Mallow was ranked as the 25th most abundant weed in 1981. Thus, populations of mallow appear to have increased.

In Manitoba (Table 1), mallow ranked highest in the Central Region. The two districts in Manitoba in which

TABLE 1. Regional Distribution of Mallow in Manitoba¹.

Region	Frequency (%)	Field Uniformity (%)	Density all fields (no. m ⁻²)	Density occurrence fields (no. m ⁻²)	Rank ²
South west	6.1	0.8	0.1	1.6	21
Central	10.8	2.4	0.2	2.1	17
Interlake	3.1	0.8	0.1	2.5	31
Eastern	14.0	1.0	0.2	1.5	19

¹Thomas and Wise (1982)²Relative abundance rank

mallow ranked the highest were the Carmen and Altona districts (Table 2). Mallow ranked as the 7th most abundant weed in Altona district and the 10th most abundant weed in Carmen district.

A frequency of 40% indicate that mallow occurred at least once in four of the ten fields surveyed in the Altona district (Table 2). Field uniformity is an indication of the distribution of the weed out of twenty samples per field. The surveys indicates that mallow is a very patchy weed, in Manitoba, Saskatchewan, and Alberta. The field uniformity of mallow in different crop species in Manitoba and Saskatchewan ranged from <0.1% to 2.4%, indicating that the weed does not occur throughout the field but in patches.

Occurrence field densities provide valuable information on the densities of weeds within the fields in which the weed occurs. The two density values given in the survey are very important. Density in all fields indicate the population of the weed throughout the district or province. The densities of mallow in occurrence fields both in Manitoba (Table 3) and Saskatchewan (Table 4) indicates that populations of mallow ranged from 0.3-2.6 plants m^{-2} in Manitoba and 0.2-1.3 plants m^{-2} in Saskatchewan. Thus, populations of mallow in occurrence fields in Manitoba are twice as high as in Saskatchewan. However, the density in all fields was similar in both provinces. The occurrence of mallow was greater in flax, wheat and oats than other crops,

TABLE 2. Occurrence of Mallow in the Altona and Carmen District¹.

District	Frequency (%)	Field Uniformity (%)	Density all fields (no. m ⁻²)	Density occurrence fields (no. m ⁻²)	Rank ²
Altona	40.0	6.0	0.3	0.8	7
Carmen	17.4	7.6	0.6	3.6	10

¹Thomas and Wise (1982)²Relative abundance rank

TABLE 3. Occurrence of Mallow in Manitoba Fields¹.

Crop	Frequency (%)	Field Uniformity (%)	Density all fields (no. m ⁻²)	Density occurrence fields (no. m ⁻²)	Rank ²
Flax	4.4	1.4	0.1	0.1	21
Wheat	7.3	1.5	0.2	2.6	14
Barley	8.1	0.9	0.1	1.1	22
Rapeseed	7.1	0.5	0.1	0.3	26
Oats	3.1	0.3	0.1	1.0	19

¹Thomas and Wise (1984)²Relative abundance rank

TABLE 4. Occurrence of Mallow in Saskatchewan Fields.

Crop	Frequency (%)	Field Uniformity (%)	Density all fields (no. m ⁻²)	Density occurrence fields (no. m ⁻²)	Rank ¹
Flax ²	1.3	0.1	0.1	0.2	54
Wheat ²	2.1	0.3	0.1	1.3	40
Barley ²	0.3	0.1	0.1	1.0	72
Rapeseed ²	1.0	0.1	0.1	1.3	52
Oats ²	0.9	0.1	0.1	0.9	62
Sunflower ³	2.0	0.1	0.1	0.2	49

¹Relative abundance rank²Thomas and Wise (1983)³Thomas and Wise (1986)

including rapeseed and barley (Table 3 and 4) (Thomas and Wise, 1982).

The occurrence of mallow in Saskatchewan fields was extremely low (Thomas and Wise, 1983). Mallow ranked higher in wheat than in other crops (Table 4). However, compared to the crops in Manitoba, based on rank, mallow was of lesser importance in Saskatchewan fields. The relative abundance of mallow in Alberta was 0.04 (Thomas and Wise, 1985). Thus, based on this relative abundance mallow ranked as the 44th most abundant weed in Alberta. Mallow was more prevalent on the fine textured soils in Alberta rather than on the coarse or medium textured soils (Thomas and Wise, 1985).

1.3.2 Competition of Weed with Crop Species

Significant decreases in crop shoot dry weight caused by mallow have been reported (Mortenson, personal communication, 1987). Mortenson (1987) reported yield losses of 56% in lentil cv. 'Laird' (Lentilla lens) and 23% in wheat cv. 'Katepwa.' (Triticum aestivum L.).

Mortenson (1986) noted that in a wheat field at Manitou, Manitoba, in an oat (Avena sativa L.) field at Raymore, Saskatchewan, and in a wheat field at Steinbach, Manitoba the grain yield of the cereals was significantly decreased as the population of mallow increased (Table 5). The number

TABLE 5. Competition of Mallow in Crops¹

Grain Yield/m ²				
Location and Type of Crop				
Hallow Density (Plants m ⁻²)	Steinbach, MB. cv. 'Neepawa' wheat (g)	Manitou, MB. cv. 'Columbus' wheat (g)	Raymore, SK. cv. 'Harmon' oats (g)	
0	244 ± 8	320 ± 8	560 ± 14	
4	208 ± 7	272 ± 5	432 ± 10	
8-12	176 ± 6	232 ± 8	448 ± 10	
16-20	184 ± 10	300 ± 10	396 ± 9	
24-28	200 ± 6	256 ± 10	404 ± 9	
32+	152 ± 6	240 ± 10	360 ± 10	
± Standard error				

¹Mortenson (1986)

of crop plants per quadrat remained constant with increasing mallow densities in the Steinbach wheat field. In contrast, in the other two fields the crop densities decreased with increased mallow populations. The infestation of mallow in the Manitou field was extremely heavy throughout large areas of the field (Mortenson, 1986).

The foregoing is the extent of available information on the competitiveness of mallow. Thus, it is important to examine crop competition with weeds of economic importance. Pavlychenko and Harrington (1934) conducted competition studies over a three year period. Wheat and flax were grown in competition with several weed species including, wild oats (Avena fatua L.), wild mustard (Sinapsis arvensis), redroot pigweed (Amaranthus retroflexus), stinkweed (Thlaspi arvensis), cow cockle (Saponaria vaccaria), and lamb's quarters (Chenopodium album) under field conditions. Weed species growing in a flax field always seriously decreased the yield. Wheat competed more effectively against the weeds than did the flax. Pavlychenko and Harrington (1934) reported that five days after germination the cereal crops had a larger leaf area than the dicotyledonous weeds at the same growth stage. This larger leaf area allowed the cereals to dominate the weed species at an early stage of growth. Weed species possessed a low germination rate when soil moisture was low, whereas cereals germinated quite well even under low moisture conditions.

Pavlychenko and Harrington (1935) reported that root competition began prior to the competition among aerial portions. Moisture is the critical limiting factor in the growth of weeds and crops on the prairies. Competition is initiated when the root systems of crops and weeds, or crops and crops, begin to overlap. The initial signs of this root interaction was in the decreased top growth. Barley cv. 'Hannchen' (Hordeum vulgare L.) competed much better than wheat cv. 'Marquis' with wild oats and wild mustard because it developed more roots than the wheat plants (Pavlychenko and Harrington, 1935).

Another study conducted by Pavlychenko (1937) showed that under competition root systems were reduced from 83 to 99 times in different plant species. Weeds and crops were grown in six inch rows with 18-20 plants per foot. The root systems of wild oats, wheat and spring rye were decreased from competition. Wild mustard retained a larger root length than wheat even after competition in six inch drill rows, with the weeds seeded between the rows (Pavlychenko, 1937).

Subsequent studies have been carried out to examine more details of competition. Other authors have also reported that flax is an extremely poor competitor. Alex (1968) observed a 61% reduction in seed production of flax due to competition with 400 cow cockle plants m^{-2} . He noted that this was due to a reduction in branching at the base of the

flax plants rather than a reduction in the stand of flax. An average of 285 flax plants m^{-2} was present in the field studies. As weed densities increased there was a marked decrease in the number of branches and flowers (Alex, 1968). There was a decrease in seed production from 101.9 g m^{-2} in weed free plots to 40.0 g m^{-2} in plots with cow cockle. The straw dry weight decreased from 237.4 g m^{-2} to 89.5 g m^{-2} in the corresponding plots.

It was also shown that as the density of cow cockle and wild mustard increased in a field of wheat, crop yields decreased (Alex, 1970). The competitive effects of the two weeds combined did not greatly increase yield reductions. The decrease in the production of dry weight by wheat was almost proportional to the dry weight produced by the increasing density of the weed species (Alex, 1970).

Flax yields were decreased five bushels per acre (314 kg ha^{-1}) (Gruenhagen and Nalewaja, 1969) by the presence of ten wild buckwheat (Polygonum convolvulus) plants per square foot (108 m^{-2}). This decrease in the yields was attributed to competition in the root zone of the weed and crop. Gruenhagen and Nalewaja (1969) reported that wild buckwheat utilized water and nitrogen more efficiently than flax and thus was better able to compete.

The competition of several crops including wheat, flax, and barley with Tartary buckwheat (Fagopyrum tataricum) at a population of 75 plants m^{-2} was ranked. Of all the crops,

flax suffered the greatest yield loss at 74% (St. Remy and O'Sullivan, 1986). The weeds were removed from plots on specified intervals. Average crop densities were 175 plants m^{-2} . St. Remy and O'Sullivan (1986) reported that the yield loss of all crops increased proportionally to the amount of time the Tartary buckwheat was present in the plots. In wheat, the yield loss increased 0.4% for each day the weed remained in the crop. However, with flax a yield loss of 1.1% occurred for each day the Tartary buckwheat remained in the plots (St. Remy and O'Sullivan, 1986).

Classical competition study designs such as these provide much of the basis of existing knowledge on weed species, however, much can be added to this information through more sophisticated analyses. A relatively new tool for the study of competition is growth analysis. This technique provides valuable additional information on the competitiveness of a troublesome weed, such as round-leaved mallow. By examining the apportionment of dry matter and leafiness of the weeds using growth analysis parameters the impact of the weed canopy on crop growth can be further understood. Growth analysis values also reflect the influence of environmental factors on the plants being studied. Thus predictions can be made on the potential seriousness of a weed.

1.3.3 Growth Analysis

Mathematical growth analysis is a valuable technique which can provide information for the understanding of the competition of plant species (Noggle and Fritz 1976, Fitter and Hay 1981, Hunt 1982, Radosevich and Holt 1984). Information collected at harvest intervals include dry matter production of various organs and leaf area. Growth analysis is a destructive technique of measuring the rate and form of growth of the plant species being studied. Growth analysis techniques were designed to quantify the various growth phases and identify critical events in the ontogenetic development of a crop and their impact on plant growth (Milthorpe and Moorby, 1974).

Three general phases of growth have been identified;

- (I) Period of accelerating growth rate.
- (II) Period of more or less constant growth rate.
- (III) Declining phase. (Milthorpe and Moorby, 1974).

Several parameters are calculated to express the growth of the plants studied (Table 6). Relative growth rate (RGR) provides quantitative information on the increase in the amount of living material produced from one harvest to the next (Wareing and Phillips, 1981). Ontogenetic patterns of RGR may vary greatly between species, and indeed between different environmental conditions for the same species. In some species there is no exponential phase, and the RGR declines from the initiation of plant growth (Phillips and

Wareing, 1970). Characteristically weeds growing in arable fields have a high relative growth rate. RGR's of chickweed (Stellaria media), field bindweed (Convolvulus arvensis), lambsquarters (Chenopodium album) and velvetgrass (Holcus lanatus) have been reported to be 2.43, 2.44, 2.12, and 2.01 respectively (Grime and Hunt, 1975). These weeds are all vigorous competitors. The accumulation of dry matter by a plant is generally considered to be proportional to the resources used for growth (Radosevich and Holt 1984). Thus the higher the relative growth rate the better the competitive ability of the plant.

Net assimilation rate (NAR) is the increase in plant weight per unit leaf area per unit time. The net assimilation rate is a measure of the photosynthetic capacity of the plant. The calculation of NAR as employed assumes a linear relationship between leaf area and plant weight. This relationship often does not hold during the later stages of the growth period and so some care must be exercised in interpreting NAR at those times. Johnsongrass (Sorghum halepense (L.) Pers.) and soybean were grown under conditions of interspecific competition (Patterson, Flint and Beyers, 1984). The NAR of soybean was $0.073 \text{ g dm}^{-2} \text{ day}^{-1}$ under competition with Johnsongrass as compared to $0.084 \text{ g dm}^{-2} \text{ day}^{-1}$ without competition. Thus johnsongrass caused a decrease in the photosynthetic capacity of the soybeans through competition.

Leaf area ratio (LAR) is a measure of the proportion of the plant which is engaged in photosynthesis (Fitter and Hay 1981, Hunt 1982, Radosevich and Holt 1984). Specific leaf area (SLA) is the measure of the changes in the structures of the leaves (Patterson, 1979). This also provides an indication of the thickness of the leaves. One attribute of a adaptable or 'plastic plant' is the ability to alter SLA with differing environmental conditions. The LAR of wild proso millet (Panicum miliaceum) was $1.48 \text{ dm}^2 \text{ g}^{-1}$ under a temperature regime of $24/18^\circ \text{ C}$, while at a regime of $30/24^\circ \text{ C}$, the LAR was $1.63 \text{ dm}^2 \text{ g}^{-1}$ (Patterson et al., 1986). Patterson et al. (1986) reported that wild proso millet produced a greater leaf area and more total weight at $30/24^\circ \text{ C}$ day/night. Wild proso millet had a SLA $4.24 \text{ dm}^2 \text{ g}^{-1}$ at 30° C while at 24° C the SLA was $3.50 \text{ dm}^2 \text{ g}^{-1}$. With an increase in temperature the leaves produced were much thinner than those at the lower temperatures. The larger LAR and SLA were due to an increase in the leaf area of the weed. Sicklepod (Cassia obtusifolia L.) and hemp sesbania (Sesbania ealtata (Raf.) Cory) were shown to increase significantly in dry weight with increased temperatures, from 23° C to 26° C (Flint et al., 1984). The SLA of these semi-tropical plants increased with increasing temperatures. The SLA of sicklepod increased from 4.36 to $5.02 \text{ dm}^2 \text{ g}^{-1}$ with increasing temperatures, which is a similar trend when temperature regimes of wild proso millet were increased (Patterson et al., 1986).

Leaf area duration (LAD) is the duration of leaf area over time. The LAD of wild proso millet increased from 29.4 dm² days to 118.3 dm² days with increasing temperature regimes (Patterson et al., 1986). The LAD of sicklepod and hemspsesbania also significantly increased with an increase in the temperature regimes (Flint et al., 1984). In both experiments researchers concluded that the modification of LAD by the temperature significantly affected the amount of the dry matter produced.

The dry matter and leaf area production of itchgrass (Rottboellia exaltata) was greatly reduced by shading. Patterson (1979) reported that under shading the leaves were thinner and less dense as indicated by the increase in the SLA. The change in the LWR indicated a change in the division of biomass favouring the production of leaf tissue under shaded conditions. Due to the decrease in the dry weight and RGR itchgrass was reported to be a shade-intolerant plant (Patterson, 1979).

Comparative analysis of several species grown under similar regimes is possible using growth analysis techniques. Such experiments provide information on the understanding of the differential success of a variety of weed species. By comparing these parameters it may be possible to better understand why certain weeds are more successful, which classical competition studies do not provide.

1.3.4 Economic Importance

Since mallow seeds are so tiny they are difficult to clean out of flax seed. During combining the seed capsules may remain whole or partially separated, and thus are also difficult to clean out of large seeded crops. In the 1981 Manitoba Seed Grain Survey (Anonymous, 1982) mallow was found five times out of 534 samples taken from farmers grain drills.

The seeds of mallow have an extremely high moisture content and when stored with the grain they will initiate heating (Hunter, 1985a). During combining the green leaves of mallow are picked up and passed into the hopper. The leaves plug the combine and can cause damage to the machinery in addition to lost harvesting time.

The potato aphid (Macrosiphum euphorbiae) overwinters in the viviparae stage on herbaceous weeds, including mallow, in eastern Washington (Landis, Powell and Fox, 1972). The potato aphid is a serious pest for potato farmers. Winter-hardy weeds and crops which germinate in the fall provide food and shelter for these insects until planting season.

The cotton seed bug (Oxycarenus hyalinipennis) is another insect which prefers mallow as a secondary host (Dimetry, 1971). This insect survives exclusively on the seeds of members of the Malvaceae. The seedlings on which the insect preferred to oviposit on are of the cotton plant (Gossypium

barbadense). Mallow seedlings or Hibiscus esculentus seedlings were chosen if cotton seedlings were 15-20 days old. This is the extent of reported information on round-leaved mallow as a host to insects which attack crop plants.

Common mallow is a closely related species of round-leaved mallow with the major difference in these plants being that the former has more kidney shaped leaves. Thus, it is possible that the following results applicable to common mallow may also apply to round-leaved mallow. It has been reported that common mallow is host to the beet western yellow virus (BWYV) (Tamaki and Fox 1982, Annis, et. al. 1981). Common mallow plants were collected from a peach orchard and fumigated to eliminate any insect contaminants (Tamaki et. al., 1980) The pots in which the plants were grown were placed on fallow approximately 150 m from the peach orchard. Pots were also placed directly below the peach trees in order to examine the spread of Green peach aphid (Myzus persicae). Common mallow plants under peach twig prunnings had seventeen times as many fundatrices (stem mothers) as the plants in the fallow region. The authors found that common mallow was preferred over any other weed for reproduction.

Plant species were obtained from three commercial orchards and three roadside ditches to test if weeds were hosts to BWYV, commonly carried by Green peach aphid (Annis et. al. 1981, Tamaki and Fox 1982). Common mallow was

shown to be a host to BWYV, which is a pathogen that causes serious injury to peach trees in orchards.

1.4 Chemical Cultural and Biological Control

1.4.1 Chemical Control

There are no references in scientific journals on the chemical control of mallow. Thus references were extracted from research reports. The results in these reports are based on a visual rating scale on the effectiveness of the herbicide in controlling the weed. In western Canada a visual rating system of 0-9 is used in ECW (Expert Committee on Weeds) reports. A value of 0 means that no weed control has been attained, while a value of 9 refers to complete weed control. The minimum commercially acceptable rating for a particular weed is 7, below which the herbicide is considered ineffective in controlling the weed.

The effect of the post-emergent herbicides cyanazine {2-[4-chloro-6-(ethylamino)-s-triazin-2-yl] amino}}, oxadiazon (2-tert-butyl-4-(2,4-dichloro-5-isopropoxyphenyl) - Δ - 1,3,4-oxadiazolin-5-one), ioxynil (4-hydroxy-3,5-diiodobenzonitrile), ethofumesate ($\pm$)-2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranyl methanesulfonate, and desmedipham [ethyl m-hydroxycarbanilate carbanilate (ester)] on mallow was examined (Jensen, 1976). Cyanazine at 1.25 kg ha⁻¹ provided the best control of mallow with little crop damage. Ioxynil and ethofumesate at rates of 0.3 and 1 kg

ha⁻¹, respectively, also provided excellent control with a rating of 9, without any crop damage.

Dichlorprop [2-(2,4-dichlorophenoxy) propionic acid] at 0.53 kg ha⁻¹ and 2,4-D ester [(2,4-dichlorophenoxy) acetic acid] also at 0.53 kg ha⁻¹ provided good control of mallow sprayed at the 5-leaf stage in a field of wheat cv. 'Columbus'. This treatment was assigned a visual rating of 8 (Donaghy and Sturko, 1983a). 2,4-D LV ester at 0.85 kg ha⁻¹ provided better control of mallow than 2,4-D amine at 0.85 kg ha⁻¹ with visual ratings of 8 and 0, respectively (Donaghy and Sturko, 1985b).

Hunter (1982a) reported that mallow sprayed at the 4-leaf stage with 2,4-D ester at 0.5 kg ha⁻¹ was acceptable. Bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) at 0.3 kg ha⁻¹ did not provide satisfactory control and regrowth of the mallow occurred. Regrowth also occurred when mallow was sprayed with 0.5 kg ha⁻¹ 2,4-D amine (Hunter, 1982b). 2,4-D ester at 0.5 kg ha⁻¹ controlled mallow; however, as the age of the plant increased, the control decreased rapidly (Hunter 1983a). At the 2-leaf stage, 0.5 kg ha⁻¹ 2,4-D ester rated 8 in pot grown mallow plants (Hunter 1983a). In contrast at the 8-leaf stage the control rating was only 2. Hunter (1983a) assessed the control of mallow by calculating the percent control by weights. At the 2-, 4-, 6- and 8-leaf stages of the weeds, 94, 82, 61 and 35 percent control was achieved, respectively. Thus as the leaf number

of mallow plants increased the control of the weed decreased.

Herbicides commonly used in wheat fields were applied to pot grown mallow plants and the visual ratings compared (Hunter 1983b). MCPA amine {[(4-chloro-o-tolyl)oxy] acetic acid} at 0.5 kg ha^{-1} did not provide adequate control over mallow and had a rating of 1. Bromoxynil at 0.3 kg ha^{-1} also received a rating of 1. Trifluralin (α , α , α -trichloro-2,6-dinitro-N,N-dipropyl -p-toluidine) at 0.8 kg ha^{-1} was given a low control rating of 1. Hunter (1983b) assigned 0.2 kg ha^{-1} metribuzin (4-amino-6-tert-butyl-3-(methylthio)-as-triazin-5(4H)-one) + 0.5 kg ha^{-1} MCPA amine a rating of 8 for its control of mallow. Of all the herbicides tested, this was the most effective.

A control rating of 7 was given to bromoxynil applied at 0.28 kg ha^{-1} on mallow plants at the 2-leaf stage in a field of wheat (Zwambag, 1985). Thus the use of a competitive crop in addition to the application of a herbicide appeared to suppress the mallow. Zwambag (1985) reported that 0.5 kg ha^{-1} 2,4-D ester + 0.52 kg ha^{-1} dichlorprop was slower acting in controlling mallow than MCPA at 0.28 kg ha^{-1} + bromoxynil at 0.28 kg ha^{-1} or bromoxynil alone at 0.28 kg ha^{-1} . However, all were rated approximately the same in the suppression of the weed.

Johnson and Donaghy (1979) reported that the level of control of mallow sprayed at the 2-leaf stage was generally

low with most herbicides tested. A rating of 9 was assigned to linuron (0.21 kg ha^{-1}) + 2,4-D ester (0.42 kg ha^{-1}) in controlling 35 mallow plants per square meter. MCPA amine at 0.68 or 0.84 kg ha^{-1} did not control mallow. Dichlorprop (0.56 kg ha^{-1}) + 2,4-D ester (0.56 kg ha^{-1}) also did not control mallow. 2,4-D ester at 0.84 kg ha^{-1} was given a rating of 0. The leaf number of mallow at the time of assessment was 99.

In a crop of wheat cv. 'Neepawa' bromoxynil at a rate of 0.28 kg ha^{-1} was rated 8, when mallow was sprayed at the 8-leaf stage (Rother, 1985). Kaskiw (1985) rated 2,4-D ester (0.5 kg ha^{-1}) + dichlorprop (0.53 kg ha^{-1}) 8 in the control of mallow in a field of oats cv. 'Fidler'. Bromoxynil based herbicides were reported to be less effective in controlling mallow than 0.5 kg ha^{-1} 2,4-D ester + 0.53 kg ha^{-1} dichlorprop (Kaskiw, 1985).

The above research indicates that herbicides such as bromoxynil and MCPA inconsistently control the growth of mallow with visual ratings ranging from 0-8. 2,4-D amine did not control mallow in any of the experiments. In contrast 2,4-D ester alone or tank mixed with a compatible herbicide consistently provided good control of mallow with a rating of 8. Dichlorprop + 2,4-D ester consistently controlled mallow with visual ratings of 7 to 8. As the leaf number of mallow increased the control decreased with all herbicides studied. The data indicate that herbicides

containing 2,4-D ester and another broadleaf weed herbicide such as dichlorprop most effectively and consistently controlled mallow.

1.4.2 Cultural Control

It has been reported the most practical control method of mallow is to prevent its infestation into new areas (Hunter, 1985a). The use of weed-free grain is the best method of control.

Hunter suggests several methods to reduce the possible problems caused by mallow. These are as follows;

(1) If mallow occurs only around the edge of the field, combine these areas separately and store the grain in a separate bin. (2) Use well ventilated wooden graineries to store grain from a field with mallow. Run the grain through a coarse screen to remove any of the green capsules which were not broken during combining.

1.4.3 Biological Control

A bioherbicide which is presently being developed for commercial use contains a naturally occurring fungal pathogen, Colletotrichum gloeosporioides f. sp. malvae, of mallow (Mortenson, 1986). The pathogen takes approximately 20 days to kill the weed (Anonymous, 1986). Mortenson

noticed that the new seedlings in the area showed signs of the wilt. Results indicate that 2-5 g per acre of the fungal pathogen will control mallow in agricultural fields.

A new product containing C. gloeosporioides is presently being developed for the control of mallow, and will be called Biomal (Anonymous, 1987). Biomal is a suspension of fungal spores of C. gloeosporioides which have been isolated from the stems of diseased mallow plants. Lesions form on the stems of mallow plants within three weeks of application followed by death or severe stunting of the plants. The fungus has been tested and been reported to be host specific (Anonymous, 1987).

Safety of the crop from infection of the fungus is assured. Mortenson (personal communication, 1987) has reported that the yield of lentils and wheat was not decreased when the crop was sprayed with Biomal. However, it was reported that the dry weight of mallow was significantly decreased by the fungal infection.

2. Materials and Methods

2.1 Pot Experiments

Growth Analysis (1985 and 1986)

Mallow seedlings were selected from a field site, (Block 1) at the University of Manitoba field plot area on campus and carefully removed for transplanting when plants were in the cotyledonary stage. The soil was washed from the roots and the seedlings were placed in 5 cm diameter Jiffy pots¹ (0.15 litres) in a Metromix 220² growing medium, containing vermiculite, perlite, sphagnum, nutrients, and trace elements. The seedlings were then placed in a growth room at 25° C, with 16-h light/8-h dark regime. After 7 days (27 May 1985, 24 May 1986) the seedlings were transplanted individually into 25 cm diameter pots (6.75 litres) filled with an unmodified clay soil³. In 1985 the soil (47% clay, 35% sand, 18% silt) was amended by shallowly incorporating 0.5 g (100 kg ha⁻¹) of ammonium phosphate (16-20-0) fertilizer per pot. A soil test conducted by the Manitoba Provincial Soils Testing Laboratory indicated that the soil contained 48 and 24 kg ha⁻¹ of nitrogen and elemental phosphorous, respectively, prior to the incorporation of the fertilizer. In 1986 the soil (43% clay, 36% sand, 21% silt)

¹ Jiffy Products (N.B.) Ltd. Shippegan, Canada.

² W.R. Grace & Co. of Canada Ltd. Ajax, Canada.

³ Cheetam Soil Supplies Co. Ltd. Winnipeg, Canada.

was amended by shallowly incorporating elemental phosphorous at a rate of 0.25 g (100 kg ha⁻¹) (0-46-0) per pot. A soil test indicated that the soil contained 172 and 27 kg ha⁻¹ of nitrogen and elemental phosphorous prior to the incorporation of the fertilizer. The pots were placed outdoors and watered from above thrice weekly as required. Mean temperatures and rainfall were recorded (Figure 2 and 3) and corresponding degree days calculated both in 1985 and 1986 (Figure 4 and 5). The experiment was arranged in a completely randomized design.

Sampling was carried out on a weekly basis, starting on 3 June 1985 and ending on 5 August 1985. Thereafter, the sampling interval was increased to two weeks until 29 August 1985 at which time the final harvest was taken. In 1986, sampling was carried out on a weekly basis starting on 27 May and ending on 6 August with the final harvest being on 20 August. Eight pots were randomly selected at each harvest. Each plant was separated into the various parts present at each sampling date, ie., roots, leaves, stems and petioles, flowers and fruits. The roots of each plant were carefully washed free of soil. Leaf area was measured using a Delta-T leaf area meter⁴. The numbers of the various parts per plant were recorded.

⁴ Burnwell, Cambridge England.

Figure 2. Maximum, minimum and mean temperatures and precipitation
for the 1985 growing season in Winnipeg, Manitoba

Figure 3. Maximum, minimum and mean temperatures and precipitation
for the 1985 growing season in Winnipeg, Manitoba

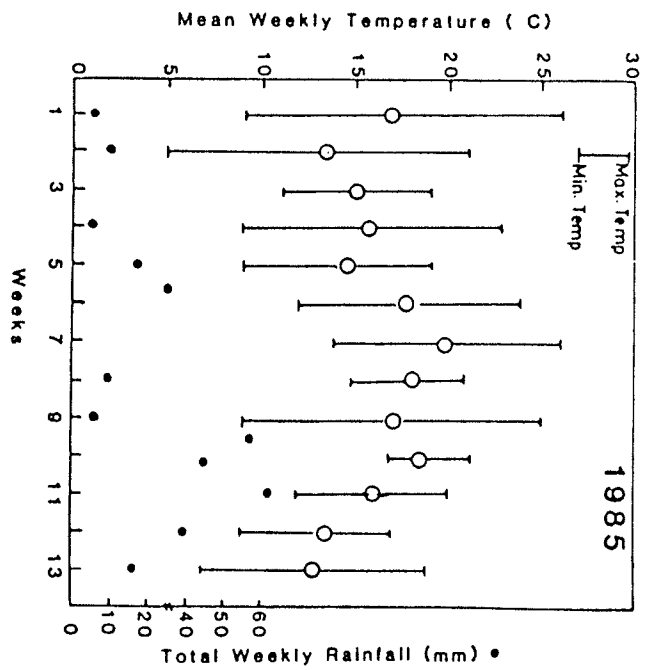


FIGURE 2.

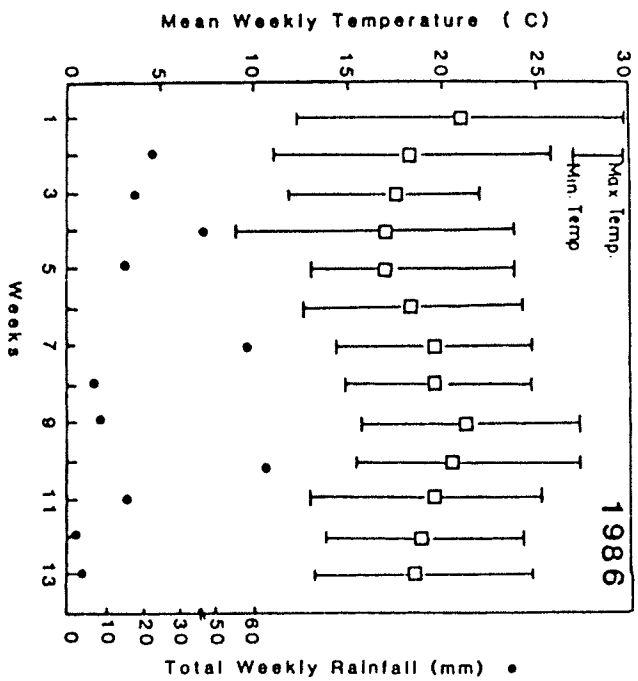
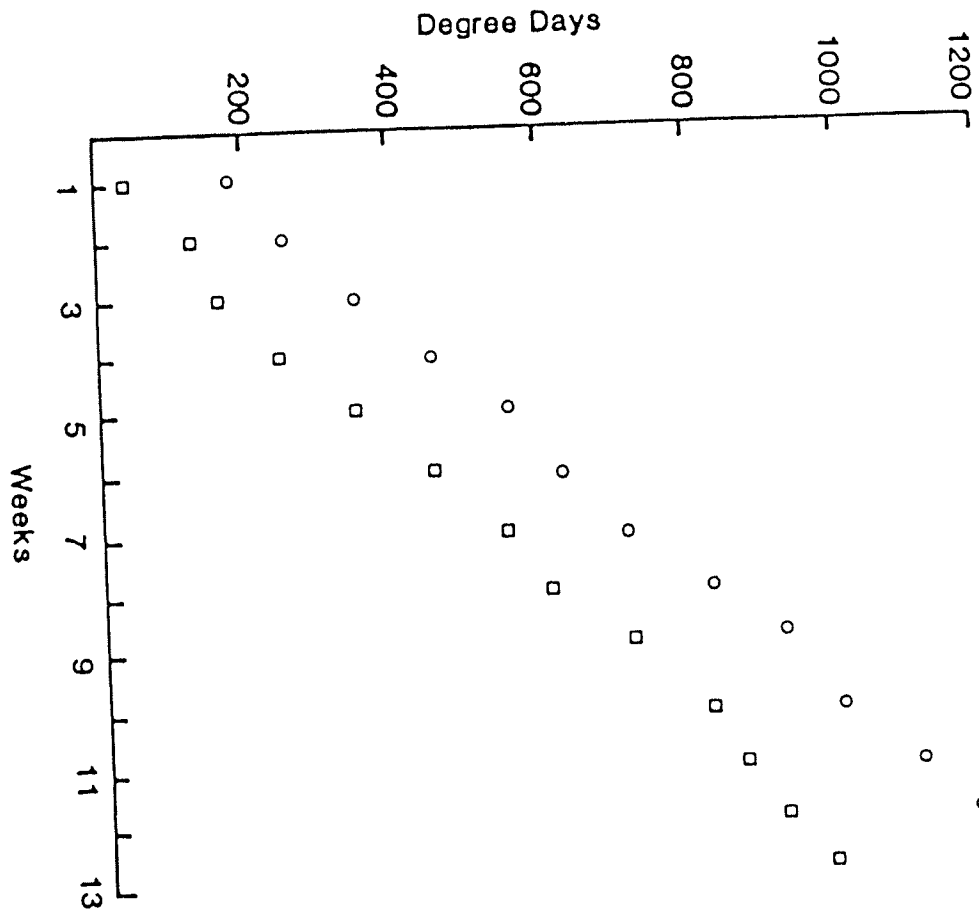


FIGURE 3.

Figure 4. Degree days for the 1985 and 1986 growing season in
Winnipeg, Manitoba

1985 □

1986 ○



The plants were then dried at 90° C for 24 hours, and the dry weights recorded. Mathematical growth analysis calculations were made as described in Table 6.

W_1 , W_2 , A_1 and A_2 represent dry weight and leaf areas at time t_1 and t_2 , two successive harvest dates.

Various dry weight ratios were also calculated including: shoot/root and leaf weight/ total weight (LWR). Statistical analysis was carried out, where appropriate, to calculate the standard error (SE) and means per harvest.

2.2 Field Experiments

2.2.1 Growth Analysis (1985)

The growth of natural infestations of mallow in fields of flax cv. 'Norlin' and wheat cv. 'Neepawa' near Manitou, Manitoba (Appendix 1) was investigated using growth analysis techniques. Field plots were selected with uniform infestations of mallow.

Plots (5m x 5m) were replicated three times for each treatment (including controls) and were established on 31 May 1985. Sowing of the crop and fertilizer application was carried out on 16 May for flax, and 19 May 1985 for wheat. Flax germinated on 25 May 1985, and the mallow germinated on 20 May 1985. Wheat germinated on 27 May, and mallow germinated on 27 May 1985. Flax was seeded with a double disk press drill at a rate of 50 kg ha⁻¹. Wheat was seeded

TABLE 6. Mathematical Growth Analysis Formulae.

Parameter Calculated	Formulae Used
Relative Growth Rate (RGR) ¹	$\frac{\frac{\ln(W_3 + W_2)}{2} - \frac{\ln(W_2 + W_1)}{2}}{t_2 - t_1}$
Net Assimilation Rate (NAR) ¹	$\frac{(W_2 - W_1)}{(A_2 - A_1)} \times \frac{\ln A_2 - \ln A_1}{t_2 - t_1}$
Specific Leaf Area (SLA) ²	$\frac{A_1}{W_1}$
Leaf Area Duration (LAD) ¹	$\frac{(A_2 - A_1)}{(\ln A_2 - \ln A_1)} \times (t_2 - t_1)$
Leaf Area Ratio (LAR) ³	$\frac{A_2 - A_1}{W_2 - W_1} \times \frac{\ln W_2 - \ln W_1}{\ln A_2 - \ln A_1}$

¹Radosevich and Holt (1984)²Hunt (1978)³Noggle and Fritz (1976)

with a double disk press drill at a rate of 120 kg ha^{-1} .

The following four treatments were applied:

- (1) Weedy, unsprayed - Flax/wheat with mallow
- (2) Weedy, sprayed - Flax/wheat with mallow; Bromoxynil and MCPA at rates of $0.28 + 0.28 \text{ kg a.i. ha}^{-1}$, were applied using a field sprayer equipped with 8002 Teejet nozzle tips by the farmer on 18 June in the flax field and 14 June in the wheat field.
- (3) Weed free, unsprayed - Flax/wheat without mallow
- (4) Weed free, sprayed - Flax/wheat, without mallow, sprayed with Bromoxynil and MCPA at a rate of $0.28 + 0.28 \text{ kg a.i. ha}^{-1}$ using a field sprayer, equipped with the same nozzles as in (2), above.

Treatments (1) and (3) were covered with tarpaulins at time of spraying. All other broad leaf weeds were removed by hand. Grass weeds were eliminated by spraying with difenzoquat (1,2-dimethyl-3,5-diphenyl-1H-pyrazolium) in wheat and sethoxydim {2-[1-(ethoxyimino)butyl]-5-[2-(ethylio)propyl]-3-hydroxy-2-cyclohexen-1-one} in flax, at the recommended rates.

Assessments: Eight subsamples (20 cm x 20 cm) were removed from each plot at each sampling date according to a predetermined randomized layout. On each of the weekly sampling dates aerial portions of the plants were collected

for analysis. Total weekly rainfall and mean temperatures were obtained from Environment Canada (Figure 5) and the corresponding degree days calculated (Figure 6).

Assessments as follows:

- (i) plant density (flax/wheat, mallow)
- (ii) shoot dry weight (flax/wheat, mallow)
- (iii) final seed yield m^{-2} (flax/wheat)
- (iv) fruit yield m^{-2} (mallow)
- (v) growth or leaf stage (flax/wheat, mallow)

Growth analyses were carried out on mallow only. Each plant was separated into the various parts present at harvest, ie. leaves, stems and petioles (combined), fruits and flowers. Leaf area was measured using a Delta-T leaf area meter. The numbers of parts were recorded and dried at 90°C for 48 hours, and the dry weights recorded. Mathematical growth analysis calculations were made as described in Table 6. Statistical analysis was carried out, where appropriate, to calculate the standard error (SE) and means per harvest.

2.2.2 Growth Analysis (1986)

The growth of mallow seeded in a field of flax cv. 'Norlin' and wheat cv. 'Neepawa' at the University of

Figure 5. Maximum, minimum and mean temperatures and precipitation
for the 1985 growing season in Manitou, Manitoba

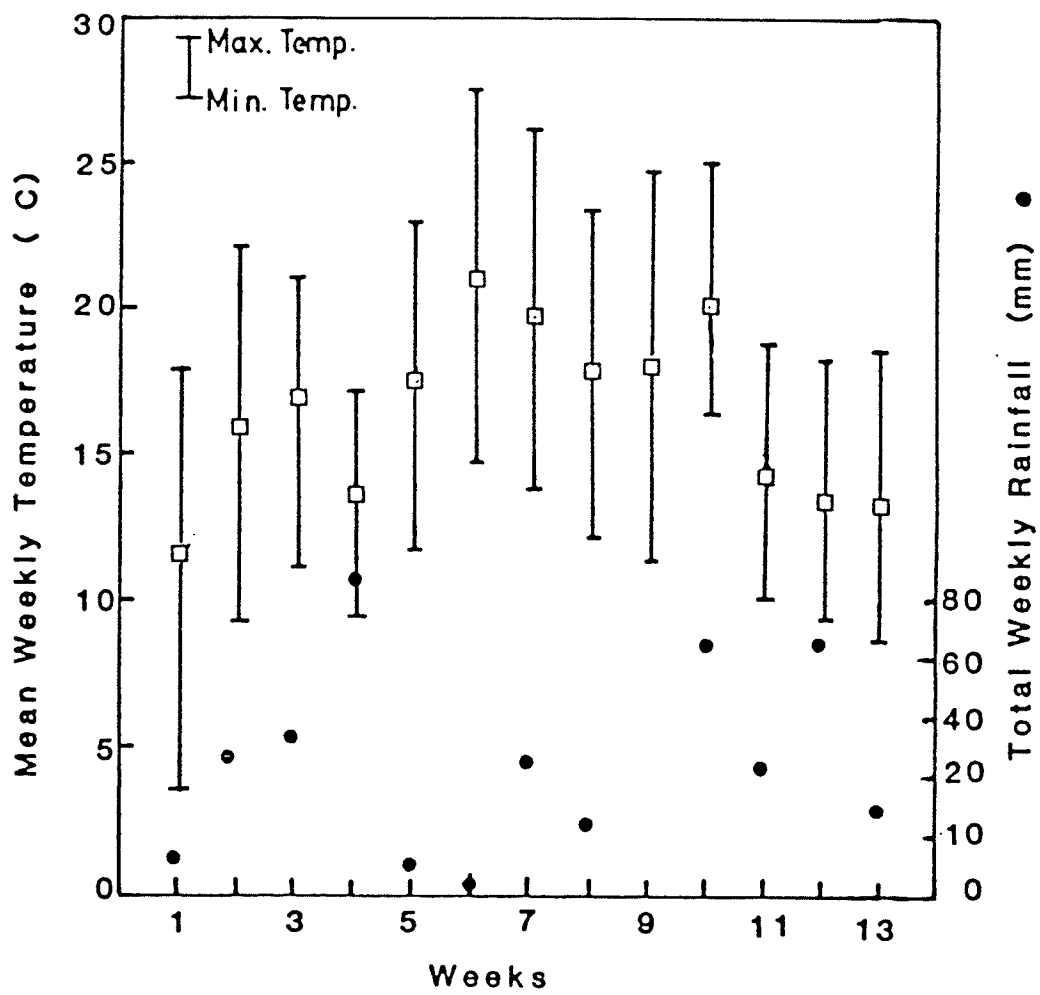
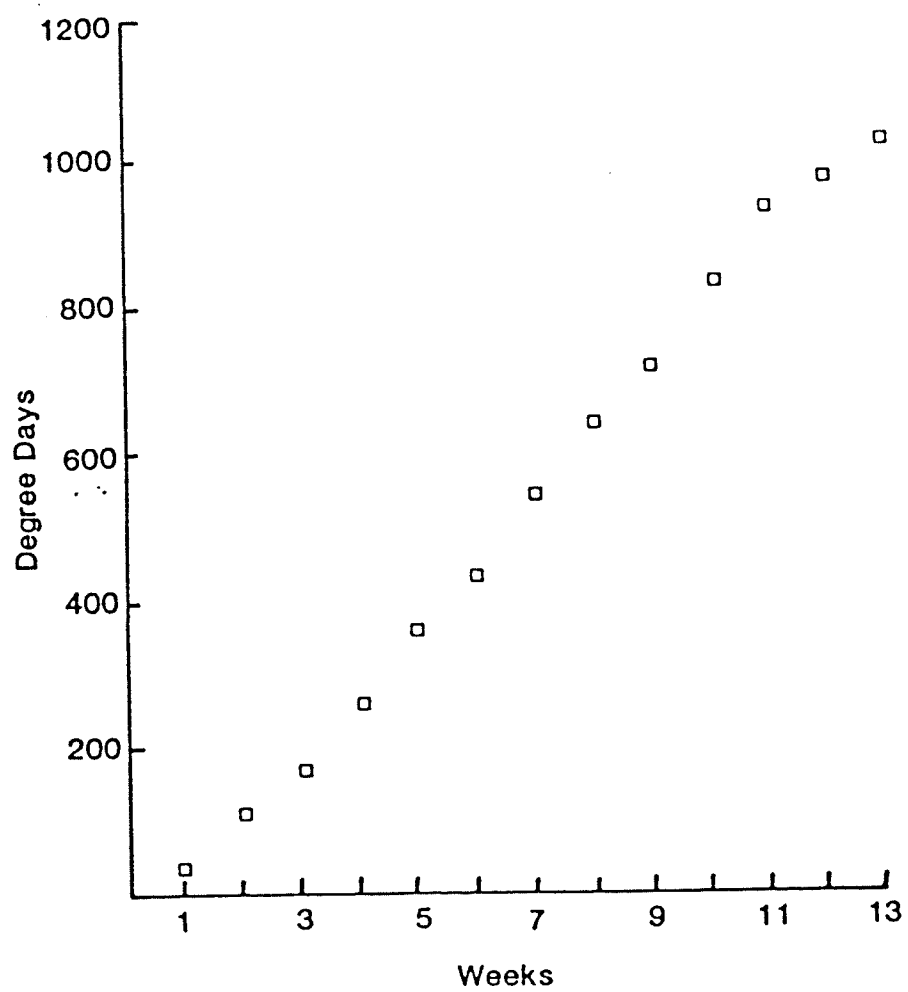


Figure 6. Degree days for the 1985 growing season in Manitou,
Manitoba



Manitoba Portage Research Station was recorded using growth analysis techniques. With the intention of establishing 50 mallow plants m^{-2} , mallow was seeded at a rate of 154 seeds m^{-2} , taking into consideration there was 36% germination and allowing for 10% seedling mortality. Seeds were broadcast by hand and shallowly incorporated with a tandem disk on 30 May. Soil tests indicated that the clay loam soil (25% sand, 44% silt, 31% clay) contained 59 and 46 kg ha^{-1} of nitrogen and elemental phosphorous, respectively. Total weekly rainfall and mean temperatures were obtained from Environment Canada (Figure 7) and corresponding degree days calculated (Figure 8).

Plots (5m x 5m) were replicated 3 times for each treatment (including controls) and were established on 30 May 1986. Sowing of the crop was carried out on 1 June 1986 using a double disk seed drill at a rate of 115 kg ha^{-1} and 47 kg ha^{-1} for wheat and flax, respectively. Flax was seeded at a depth of 2.5 cm, and wheat at a depth of 3.5 cm. For both crops the rows were 15 cm apart. Flax and wheat germinated on 5 June, and the mallow germinated on 13 June 1986.

Treatments were applied in the same way as in 1985 except that the bromoxynil and MCPA were applied using a bicycle sprayer equipped with Teejet 8001 nozzle tips at a rate of 0.28 + 0.28 kg a.i. ha^{-1} on 17 June. The herbicide was applied at a volume of 100 l ha^{-1} at 276 Kpa pressure.

Figure 7. Maximum, minimum and mean temperatures and precipitation
for the 1986 growing season at the Portage la Prairie
Research Station, Manitoba

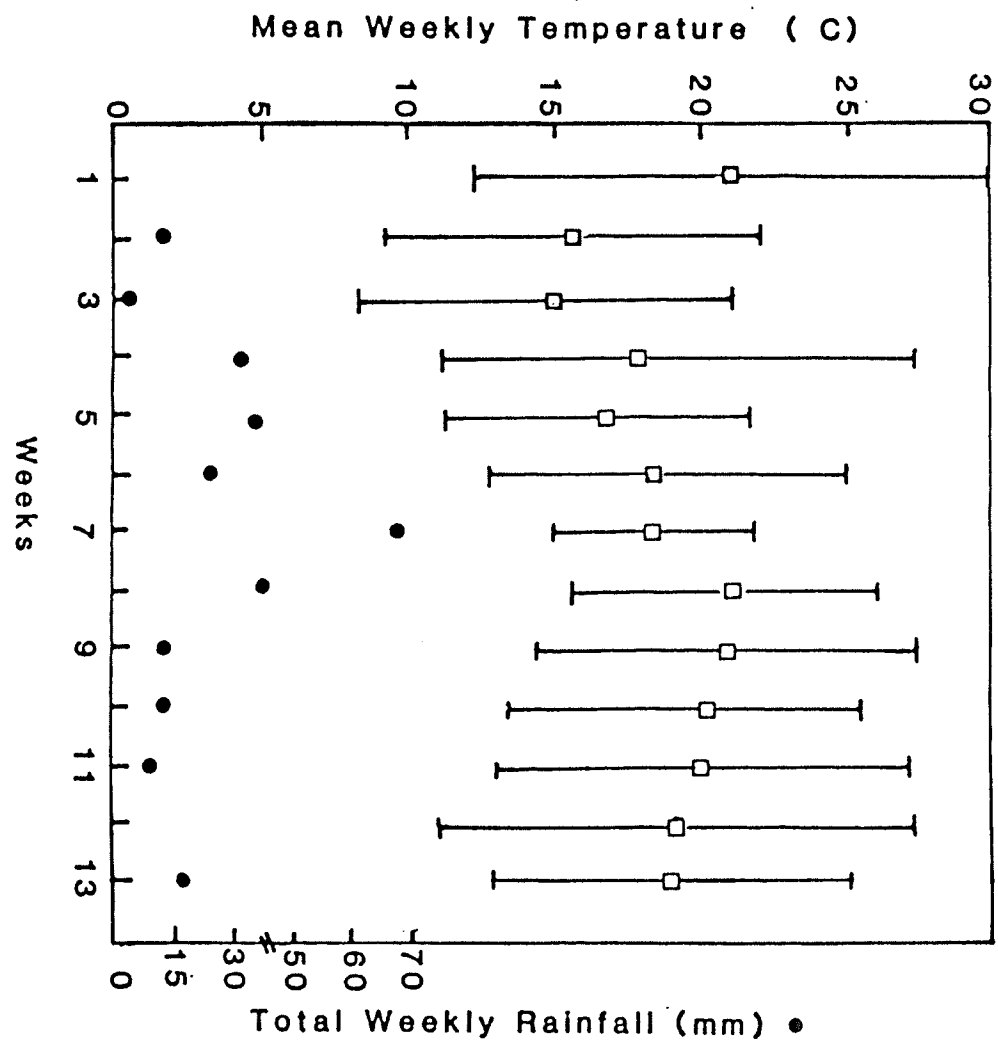
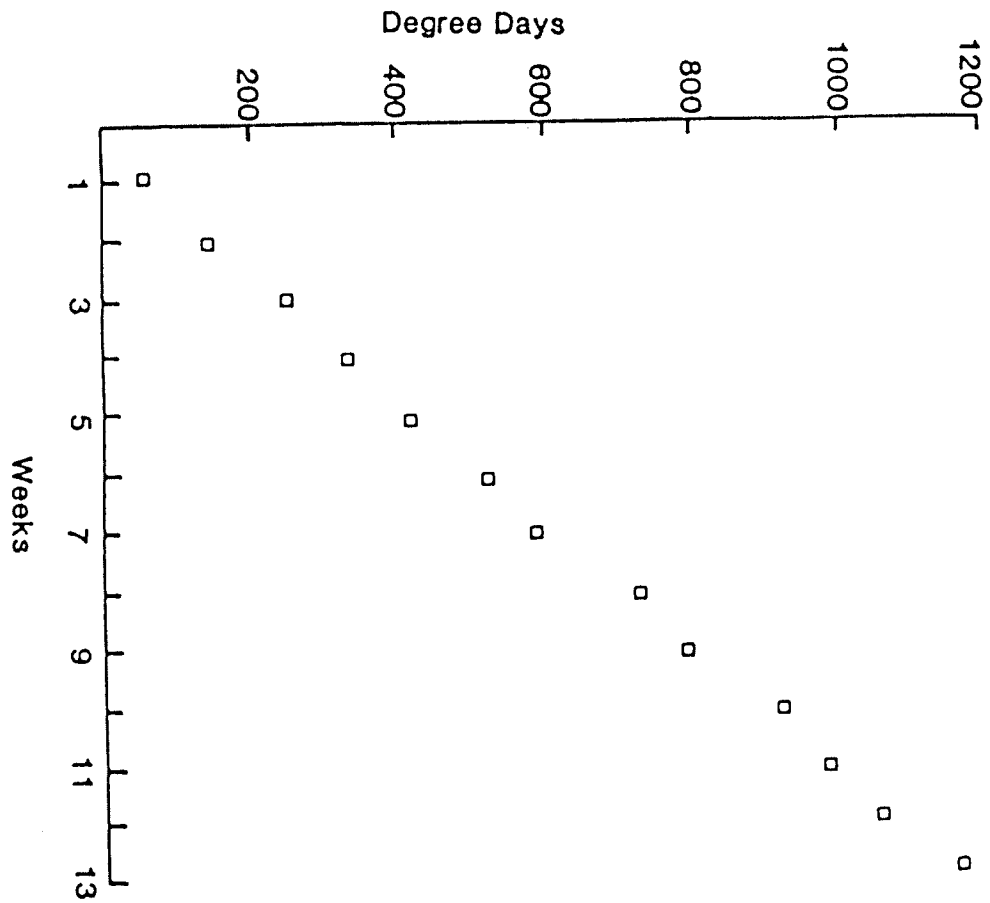


Figure 8. Degree days for the 1986 growing season at the Portage
la Prairie Research Station, Manitoba



Assessments were the same as in 1985.

2.3 Germination Studies

Mallow seeds were obtained from pot plants grown in 1985.

Twenty seeds were placed on two no. 1 filter papers in each of five 9 cm petri dishes. Distilled water was then added thrice weekly. The dishes were placed in a germinator set at a 22° C, 14-h light/18° C, 10-h dark regime.

Germination was observed on a regular basis for 40 days. Any seeds that produced a radical 5 mm long were counted and removed. Mechanical scarification was carried out by rubbing the seeds in a circular motion with sand paper for 30 seconds.

The following four treatments were included:

- (1) Mallow seeds stored at -2° C
- (2) Mallow seeds stored at -2° C and scarified
- (3) Mallow stored at 20° C
- (4) Mallow stored at 20° C and scarified

3. Results

3.1 Pot Experiments (1985 and 1986)

The growth of mallow (M. pusilla Sm.) was studied in plants grown outdoors over a period of 12 and 13 weeks in 1985 and 1986, respectively.

The total accumulation of dry matter was drastically different between 1985 and 1986 (Figure 9a and 9b). In the second year dry matter accumulation was four times greater than in the first year. Although the total dry matter accumulation varied in the 2 years, in both 1985 and 1986 growth followed a similar pattern. In both years the relative allocation of biomass toward the various structures was similar, with accumulation of fruit dry matter being the greatest. In 1985 (Figure 9a), at week 12, the final root dry weight was low in relation to the final aerial biomass (Table 7). However, in 1986 (Figure 9b) the final root dry weight was high compared to the aerial portions of the plant (Table 7, shoot/root ratio). Dry matter accumulation in 1986 (Figure 9b) was mainly in the stems, petioles and the fruits. Initially the leaves constituted a large portion of the aerial biomass with the LWR being 0.75 g g^{-1} (Table 7) in both years.

The LWR (Table 7) of mallow was approximately 0.75 g g^{-1} for the first three weeks of growth and declined as the

Figure 9. (a) Pattern of dry matter distribution in pot grown mallow in 1985

(b) Pattern of dry matter distribution in pot grown mallow in 1986

Fruits, flowers, roots, stems and petioles indicated on 9b follow the same design for 9a.

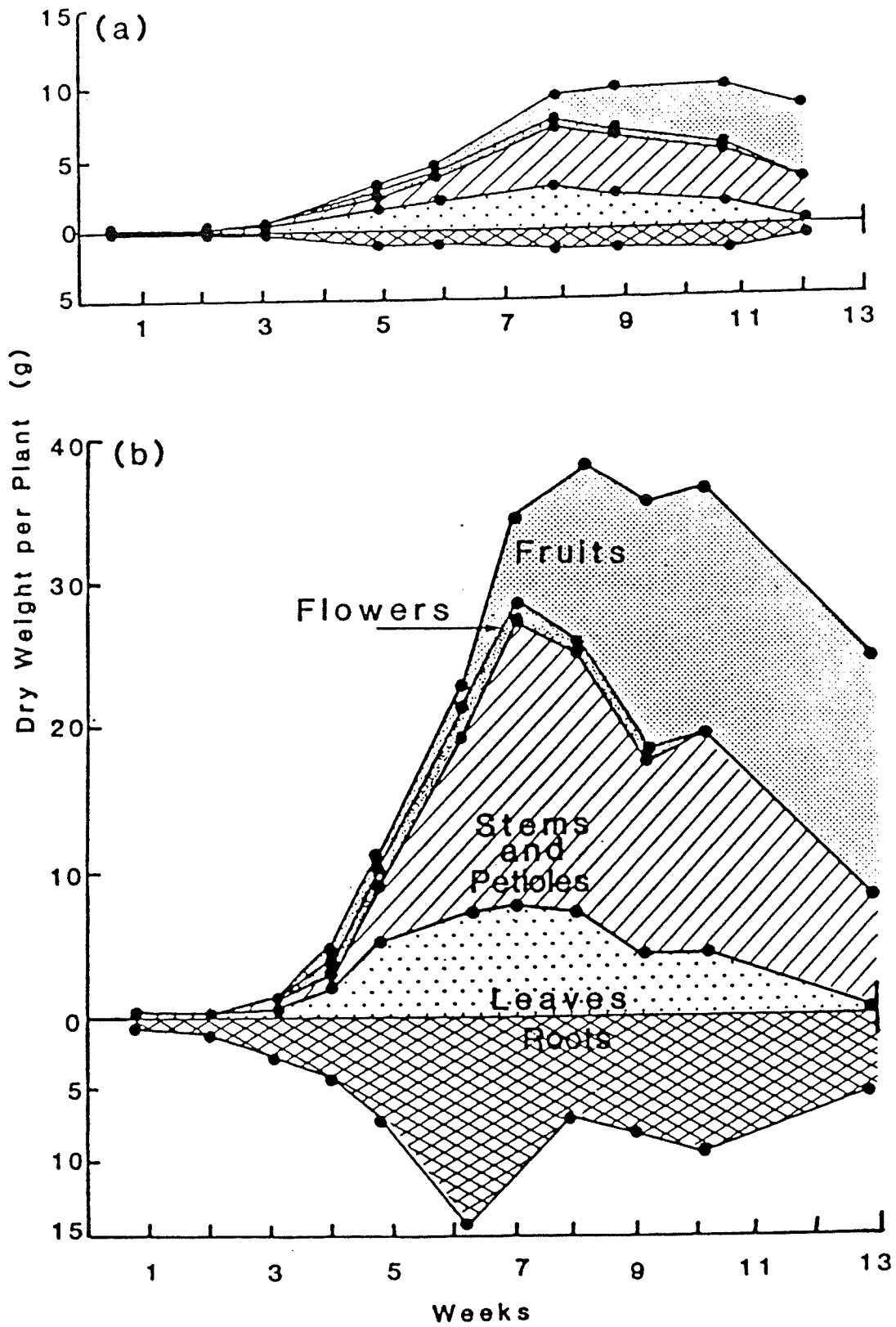


TABLE 7. Growth Analysis of Mallow in Pots Grown Outdoors (1985/1986).

Growth Analysis Parameters					
Sample Weeks	Date	LWR g g^{-1}	SLA $\text{cm}^2 \text{g}^{-1}$	LAD $\text{cm}^2 \text{week}^{-1}$	$\frac{\text{shoot}}{\text{root}}$
<u>1985</u> ¹					
2	03/6/85	0.75	618	2	0.52
3	10/6/85	0.75	221	9	3.01
4	17/6/85	0.70	263	84	3.33
6	01/7/85	0.69	244	169	2.82
7	08/7/85	0.53	208	475	2.73
8	15/7/85	0.46	192	420	4.81
9	29/7/85	0.33	162	575	6.60
11	12/8/85	0.26	280	526	6.85
13	26/8/85	0.21	197	68	4.58
<u>1986</u> ²					
2	27/5/86	0.76	281	5	2.96
3	04/6/86	0.76	388	36	2.05
4	11/6/86	0.65	233	139	1.37
5	19/6/86	0.62	149	319	1.20
6	25/6/86	0.56	137	514	1.41
7	02/7/86	0.40	90	1683	1.52
8	09/7/86	0.32	143	989	3.13
9	16/7/86	0.29	99	1012	3.84
10	23/7/86	0.27	63	431	2.30
13	14/8/86	0.22	60	81	2.46

¹Planting date 27/5/85²Planting date 24/5/86

weight of the stems, petioles and fruits increased. As the mallow plants increased in age the leaves progressively changed in thickness as indicated by the progressive reduction in SLA (Table 7).

The maximum total leaf area in 1986 was considerably larger than in 1985. In 1985 (Figure 10a) the leaf area reached 650 cm² in week 10. In contrast, 1986 (Figure 10b) the maximum leaf area was 1283 cm² at week 7 which coincided with the onset of flowering. After the leaf area attained its maximum in both 1985 and 1986 there was a steady decline in the leaf area as the plants senesced. In 1985 and 1986 the LAR (Figures 11a and 11b) of mallow followed a similar pattern. There was a steady decline in the LAR after the maximum was reached in both years.

The maximum leaf RGR for mallow in 1985 and 1986 exceeded 2.0 g g⁻¹ week⁻¹ (Figure 12 and 13). The RGR of the leaves initially was high in both 1985 and 1986 (Figures 12 and 13) and declined throughout the growth period. The leaves and the roots were the first structures to be produced by mallow. In 1985 and 1986 (Figures 12 and 13, respectively) the root RGR, leaf RGR, and stem and petiole RGR followed similar patterns of growth. The RGR of all plant parts in both years was high, exceeding values of 1.5 g g⁻¹ week⁻¹ and declined in a similar manner. This pattern of growth will be referred to as integrated; ie. all plant parts followed similar growth patterns.

Figure 10. (a) Leaf area of mallow grown in pots (1985)

(b) Leaf area of mallow grown in pots (1986)

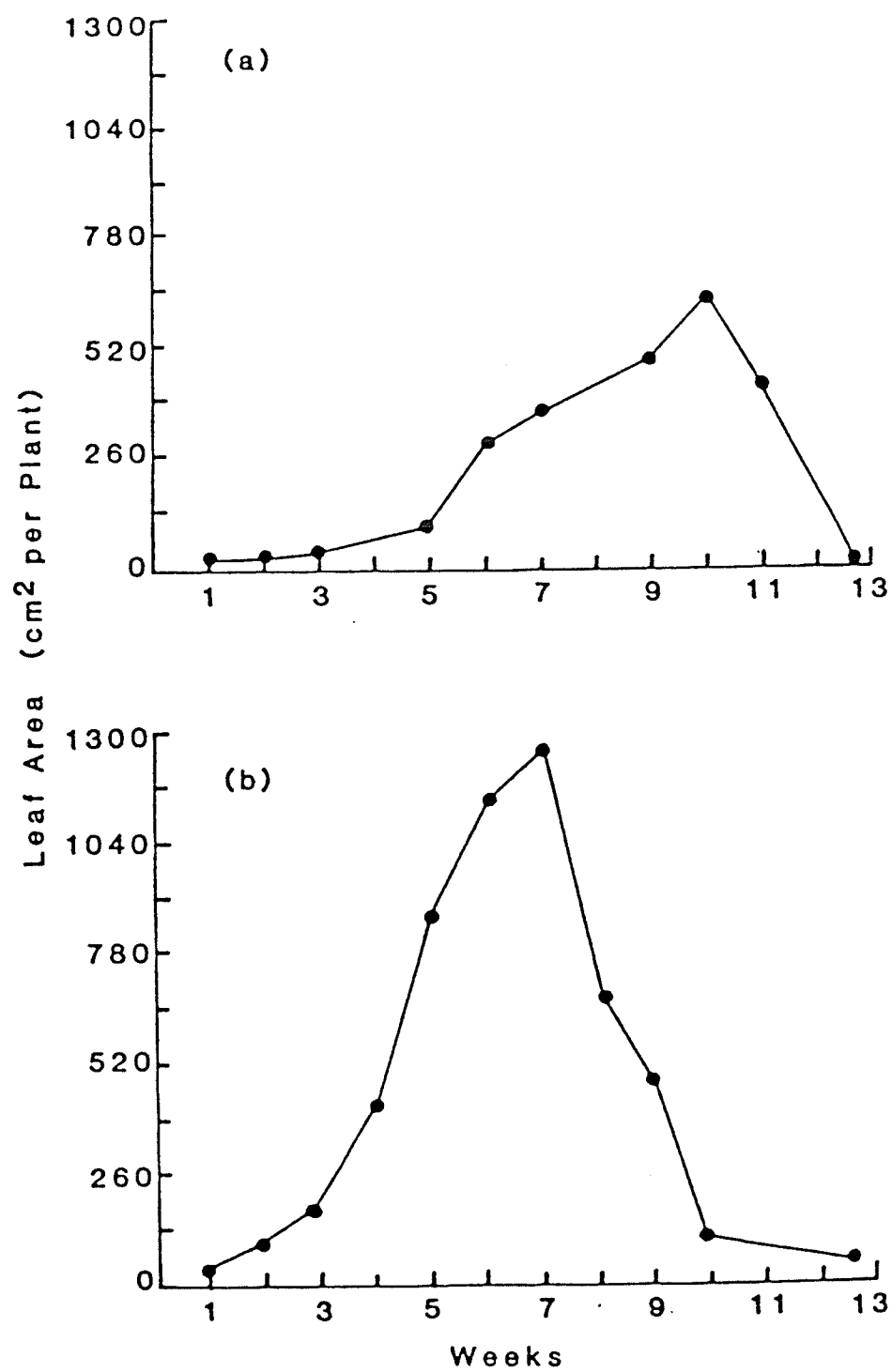


Figure 11. (a) LAR of mallow grown in pots (1985)

(b) LAR of mallow grown in pots (1986)

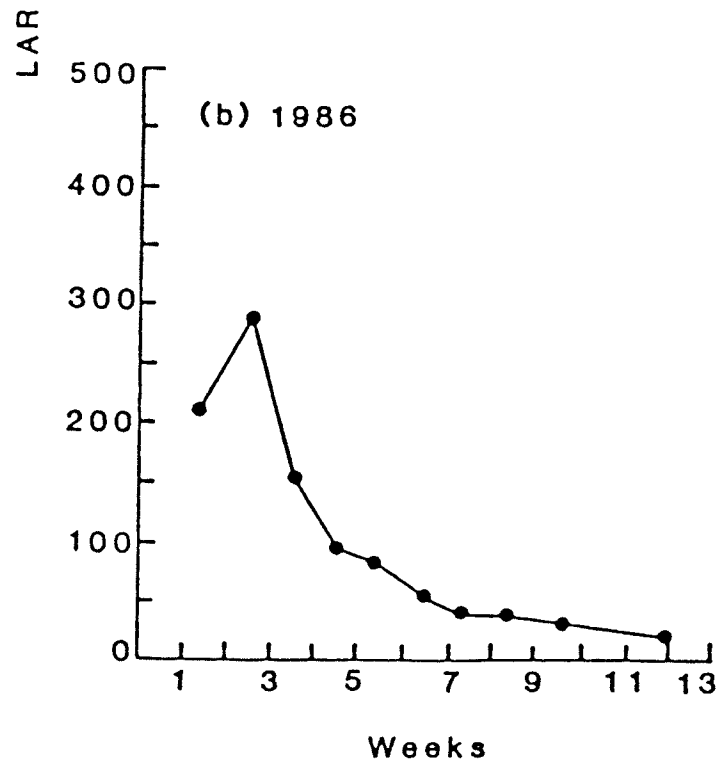
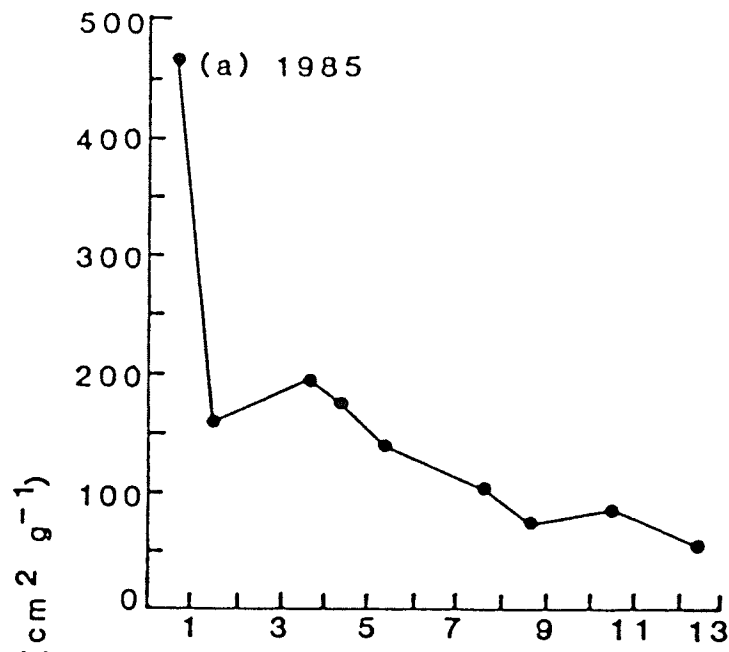


Figure 12. RGR of mallow grown in pots (1985)

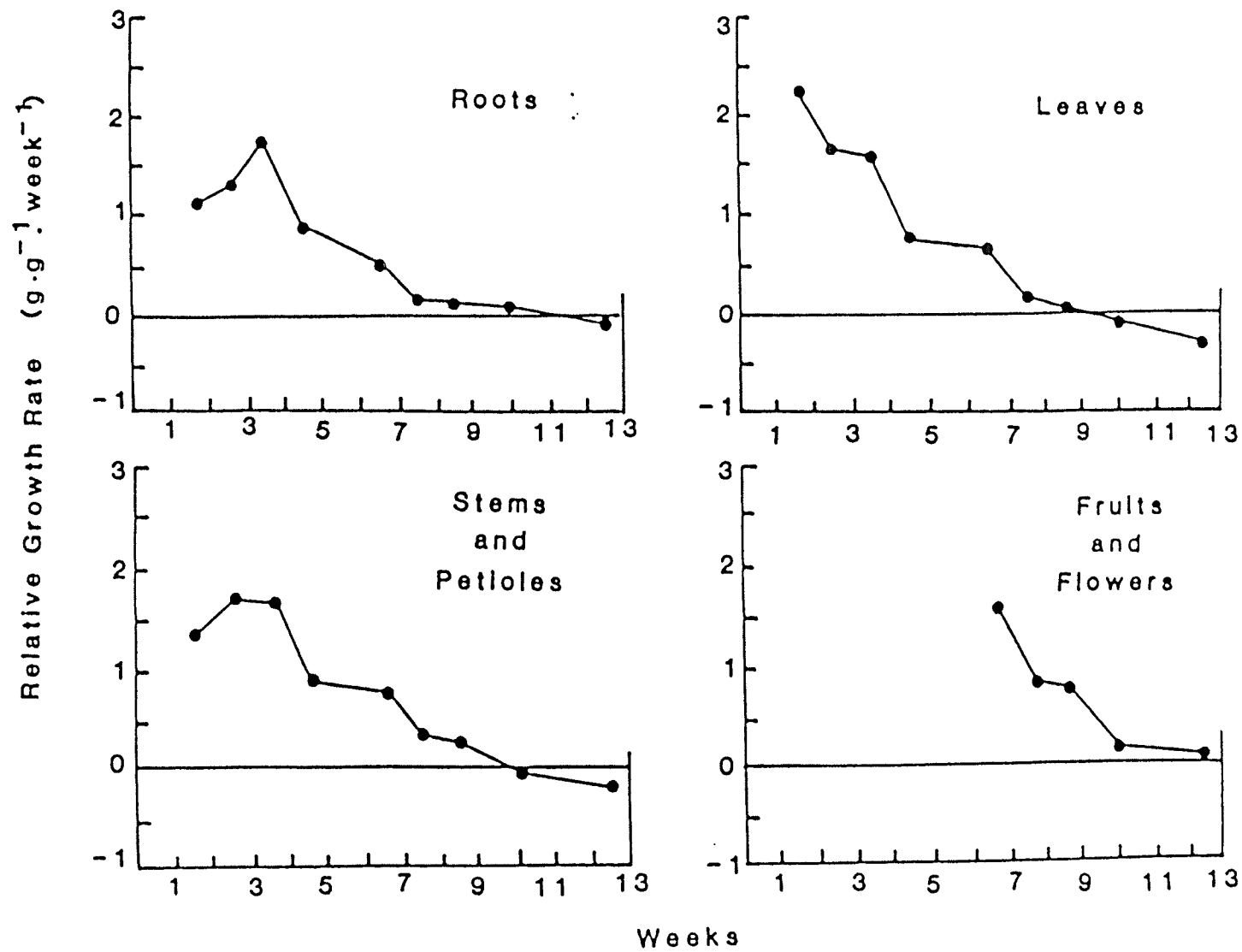
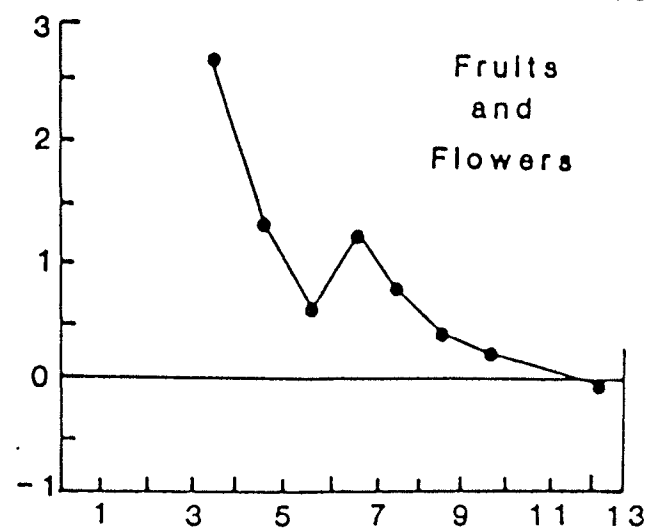
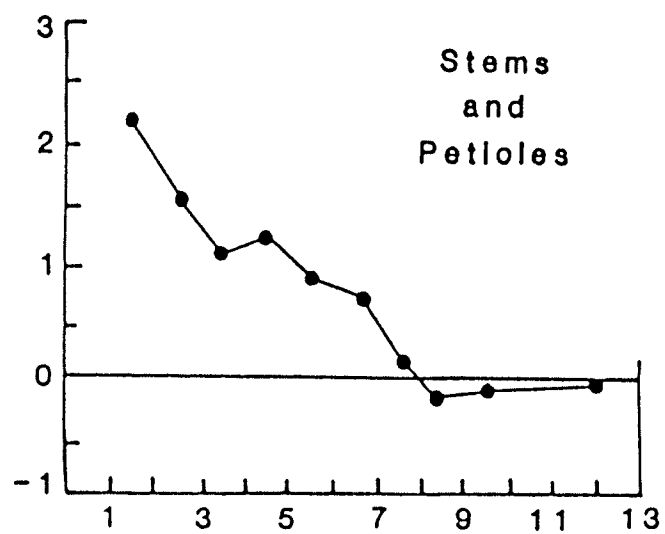
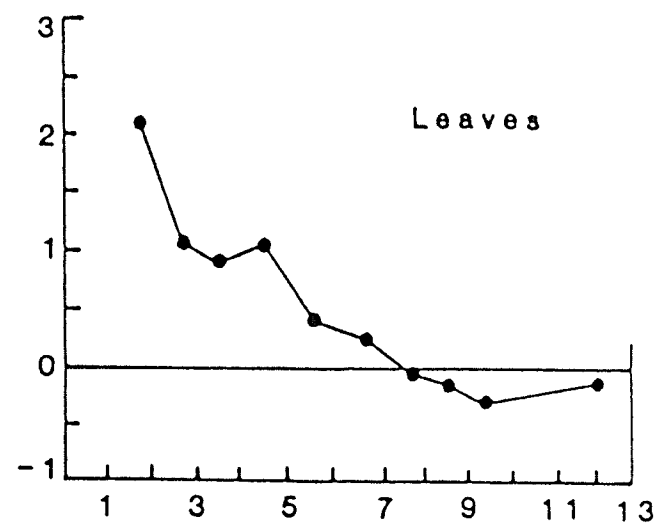
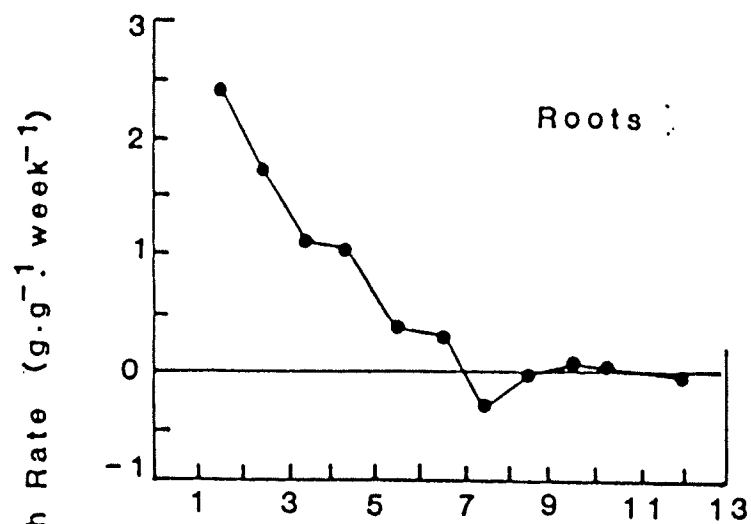


Figure 13. RGR of mallow grown in pots (1986)



Weeks

NAR was calculated for only the first 6 weeks of growth due to lack of a recognizable logarithmic relationship (Radford, 1967) between leaf area and plant weight after this time (Figures 14 and 15). In 1985 and 1986 the NAR (Figures 16a and 16b) followed a similar straight line pattern of growth. The LAD initially started low in 1985 and 1986 (Table 7) but increased about week 6 and then remained relatively constant until senescence.

In comparing weather conditions in 1985 and 1986 (Figure 2 and 3), it is evident that the mean weekly temperature in 1986 was higher by five degrees on most days throughout most of the summer. The degree days accumulated in 1986 were 998 while in 1985 the degree days totalled 1101 (Figure 4).

3.2 Field Experiments

3.2.1 1985

3.2.1.1 Crop Establishment

The growth of mallow was studied under field conditions in flax and wheat fields at Manitou, Manitoba (Appendix 1) in 1985. Growth of mallow was initiated prior to the germination of flax on 16 May 1985, and of wheat on 19 May 1985.

A population of 112 flax plants m^{-2} was established in week 0 the final density was 130 plants m^{-2} (Figure 17) in

Figure 14. Leaf area-Dry weight accumulation of mallow 1985

Figure 15. Leaf area-Dry weight accumulation of mallow 1986

Numbers indicate successive sampling dates

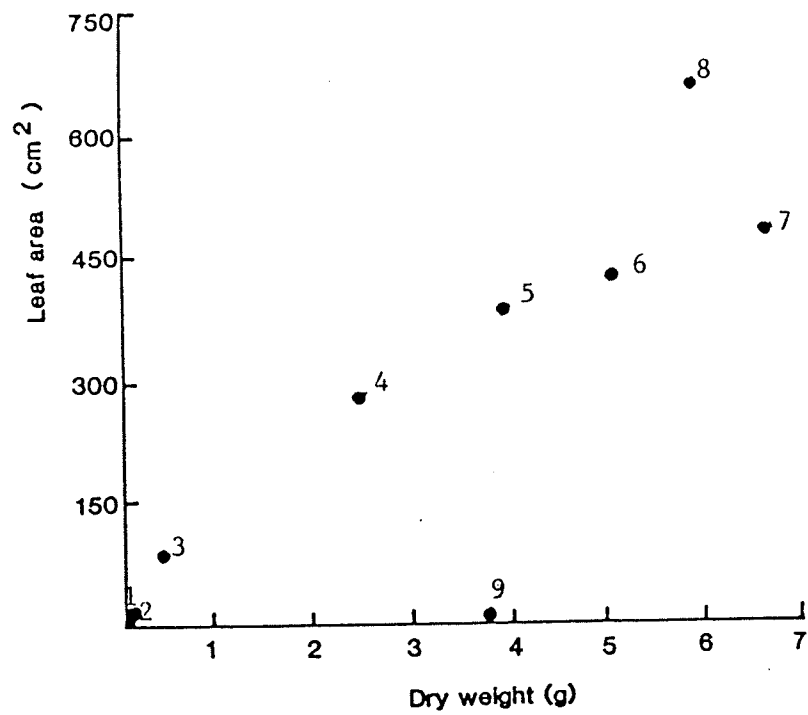


FIGURE 14.

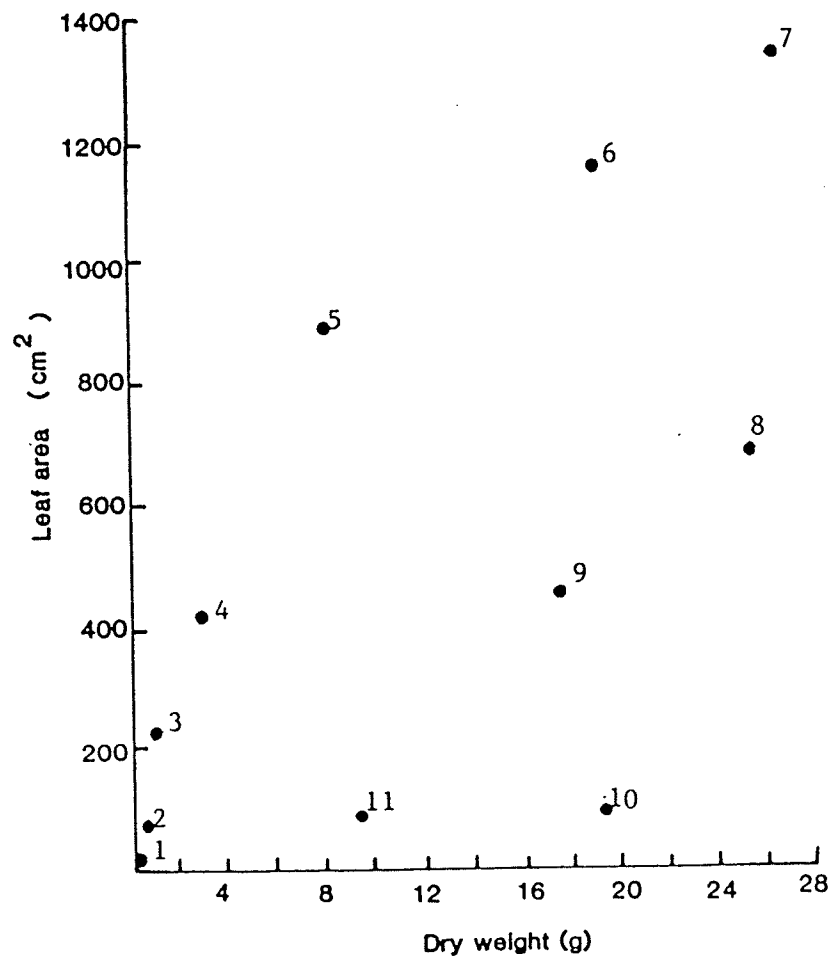


FIGURE 15.

Figure 16. (a) NAR of mallow grown in pots (1985)
(b) NAR of mallow grown in pots (1986)

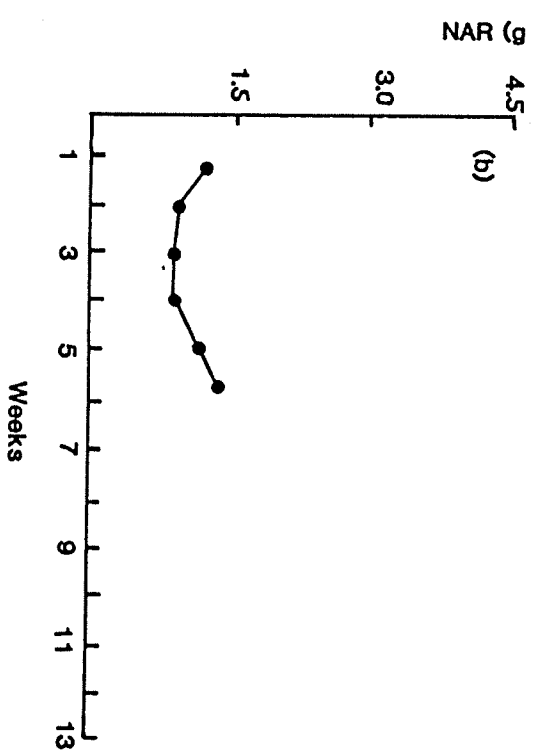
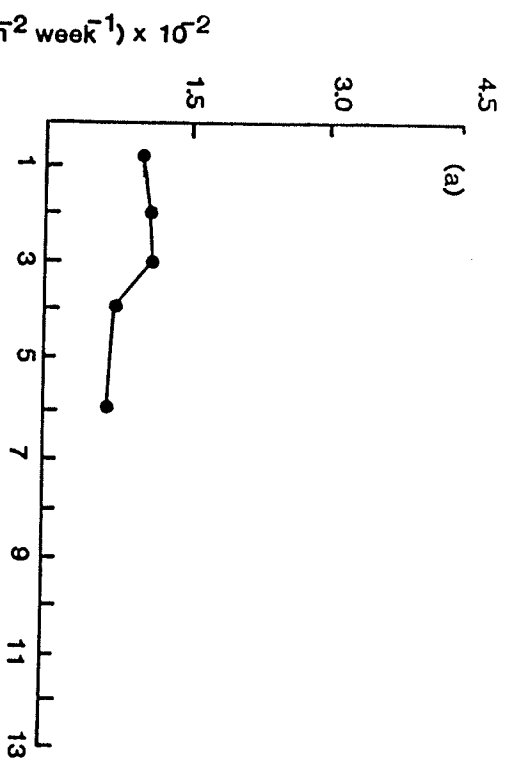


Figure 17. (a) Density of flax plants in a field infested with mallow at Manitou, Manitoba

(b) Dry weight of flax plants in a field infested with mallow at Manitou, Manitoba

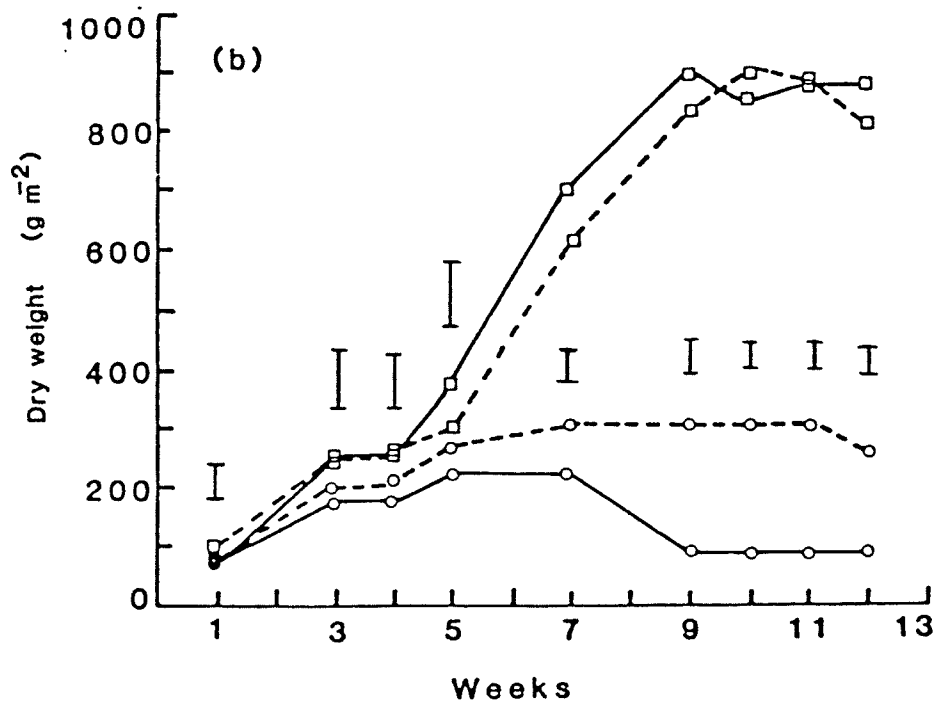
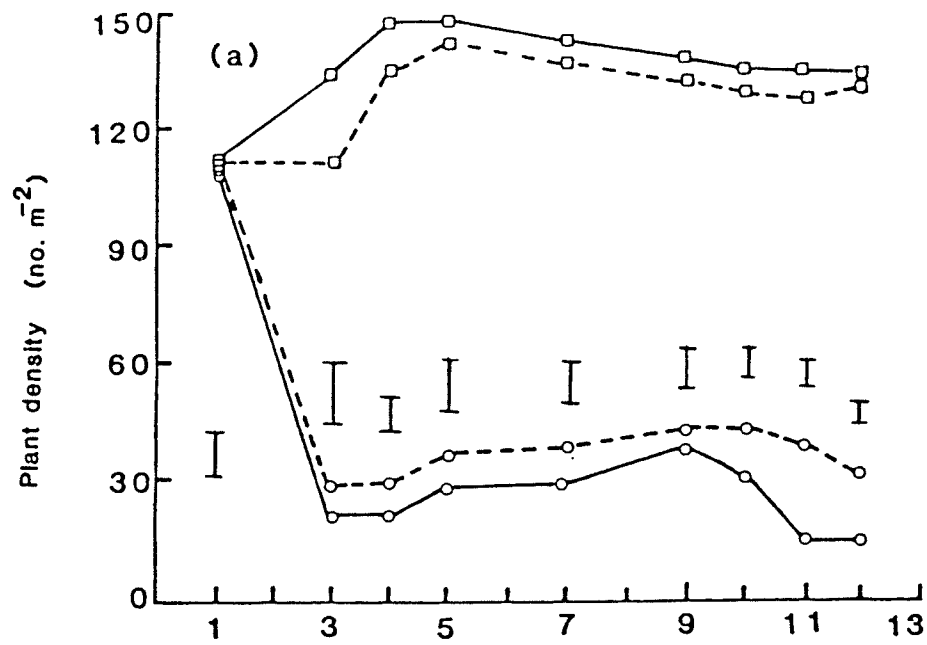
Weedy —○

Weedy-sprayed — —○

Weed free —□

Weed free-sprayed — —□

┌ Least Significant Difference



the weed-free plots. In weedy plots the population rapidly decreased to 27 plants m^{-2} in unsprayed plots, further reducing to final population of 23 plants m^{-2} at the end of the season. Prior to the application of bromoxynil and MCPA the population was 30 flax plants m^{-2} with a final density of 31 plants m^{-2} at last count. Thirty-nine mallow plants m^{-2} were established in the weedy plots with the final density declining to 25 m^{-2} .

In the wheat field in weed-free plots a population of 150 wheat plants m^{-2} was established in week 0 with the final density being 269 plants m^{-2} (Figure 18). In weedy plots the final population was 210 plants m^{-2} . In contrast the weedy sprayed plots had a final density of 239 wheat plants m^{-2} (Figure 18). A maximum population of 87 mallow plants m^{-2} (Table 8) was established in the wheat field with the numbers reducing to 17 m^{-2} by the end of the season in the unsprayed plots.

3.2.1.2 Growth Analysis

In comparing the RGR of mallow in both flax and wheat fields different patterns can be seen (Figures 19 and 20, respectively). The leaves of mallow in both fields became chlorotic and necrotic at week 8, following the initiation of flowering. The stems and petioles of mallow in the flax field had a positive RGR until week 11, after which senescence of the stems and petioles began. The RGR of

Figure 18. (a) Density of wheat plants in a field infested with mallow at Manitou, Manitoba

(b) Dry weight of wheat plants in a field infested with mallow at Manitou, Manitoba

Weedy —○

Weedy-sprayed — —○

Weed free —□

Weed free-sprayed — —□

[Least Significant Difference

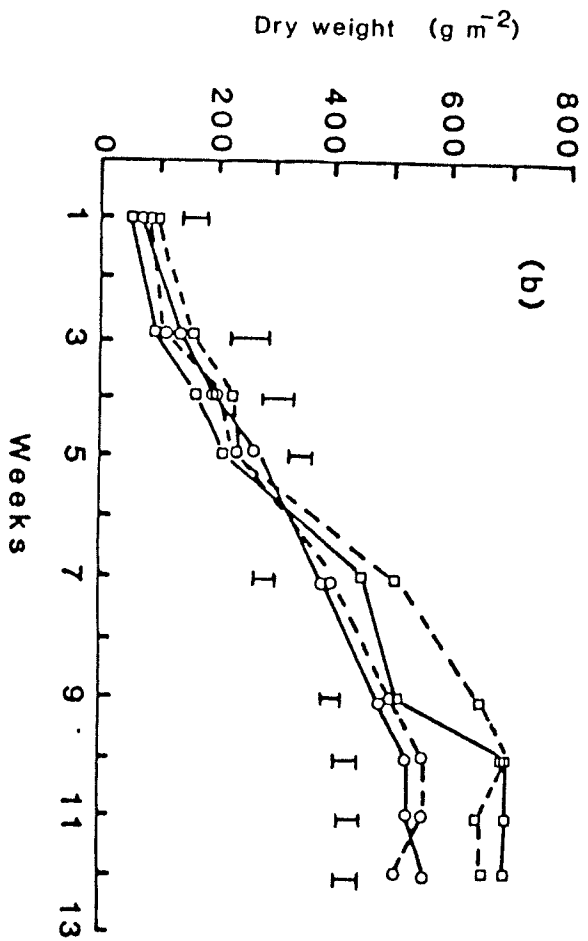
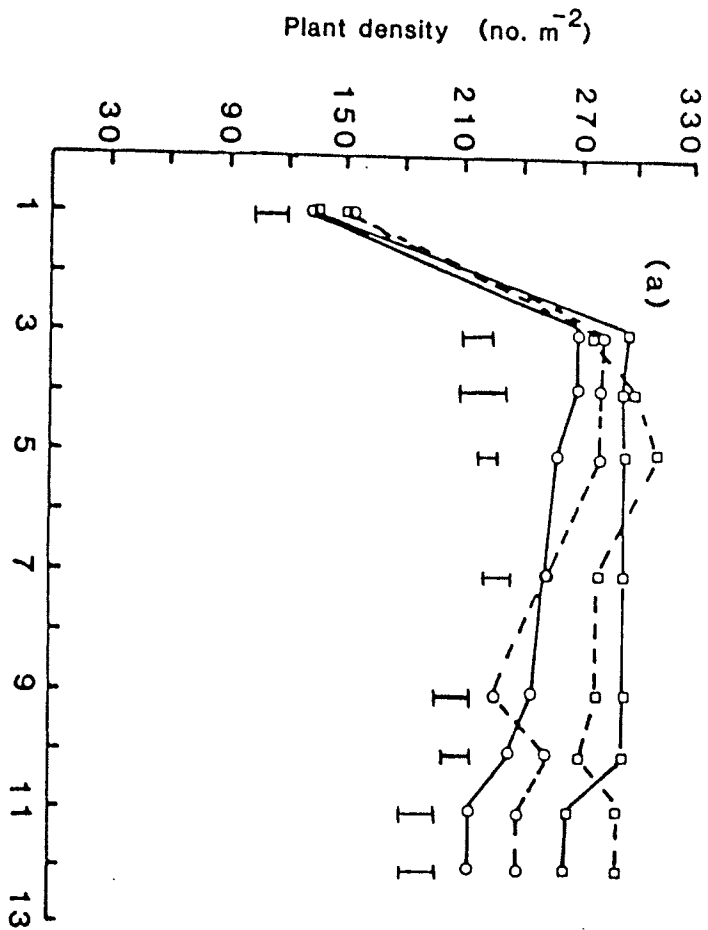


TABLE 8. Density, Growth Stage and Dry Weight of Mallow, Sprayed and Unsprayed, at Manitou, Manitoba (1985).

Sample Weeks	Date ¹	Unsprayed			Sprayed ²		
		Density (plants m ⁻²)	Growth Stage (leaves per plant)	Dry Weight (g /m ⁻²)	Density (plants m ⁻²)	Growth Stage (leaves per plant)	Dry Weight (g)
<u>Flax</u>							
1	31/5/85	29 ± 3.1	2 ± 0.3	0.9 ± 0.1	44 ± 4.4	5 ± 0.4	2.9 ± 0.5
2	07/6/85	39 ± 1.6	5 ± 0.8	2.1 ± 0.6	40 ± 3.2	3 ± 0.2	9.6 ± 0.9
4	21/6/85	39 ± 3.9	15 ± 1.2	36.8 ± 1.7	38 ± 1.6	8 ± 1.1	15.8 ± 1.4
5	29/6/85	36 ± 2.8	22 ± 3.3	75.8 ± 4.4	28 ± 2.9	10 ± 1.4	19.6 ± 1.6
7	12/7/85	28 ± 1.0	35 ± 4.0	192.0 ± 46.7	38 ± 3.1	12 ± 2.0	26.9 ± 2.9
8	19/7/85	27 ± 0.9	30 ± 3.6	222.6 ± 27.9	33 ± 0.8	61 ± 4.3	61.5 ± 4.5
9	26/7/85	27 ± 3.2	29 ± 3.2	237.7 ± 27.5	52 ± 1.7	130 ± 5.0	113.0 ± 21.6
13	18/8/85	25 ± 1.8	5 ± 0.5	197.1 ± 26.8	40 ± 2.9	195 ± 4.7	156.3 ± 18.5
<u>Wheat</u>							
1	31/5/85	5 ± 1.0	0 ³ ± 0.02	0.01 ± 0.01	4 ± 3.2	0 ± 0.0	0.004 ± 0.007
2	07/6/85	56 ± 7.9	2 ± 0.1	0.6 ± 0.1	48 ± 8.4	2 ± 0.2	5.1 ± 2.1
4	21/6/85	87 ± 8.6	5 ± 0.9	4.4 ± 1.3	75 ± 7.5	4 ± 0.6	9.7 ± 5.5
5	29/6/85	50 ± 6.1	5 ± 0.8	6.3 ± 0.7	22 ± 3.4	4 ± 0.8	11.7 ± 1.5
7	12/7/85	25 ± 3.4	7 ± 1.4	16.4 ± 0.6	21 ± 2.8	6 ± 1.2	23.8 ± 1.2
8	19/7/85	24 ± 4.1	8 ± 2.5	24.8 ± 2.0	16 ± 2.1	8 ± 2.1	26.2 ± 8.2
9	26/7/85	17 ± 2.6	6 ± 2.7	27.5 ± 1.2	18 ± 1.7	6 ± 0.9	23.3 ± 2.2
13	18/8/85	17 ± 2.9	4 ± 1.3	9.7 ± 1.4	15 ± 1.8	4 ± 0.8	13.4 ± 0.6

¹Crop Germination 25/5/85-Flax 27/5/85-Wheat

± Standard Deviation

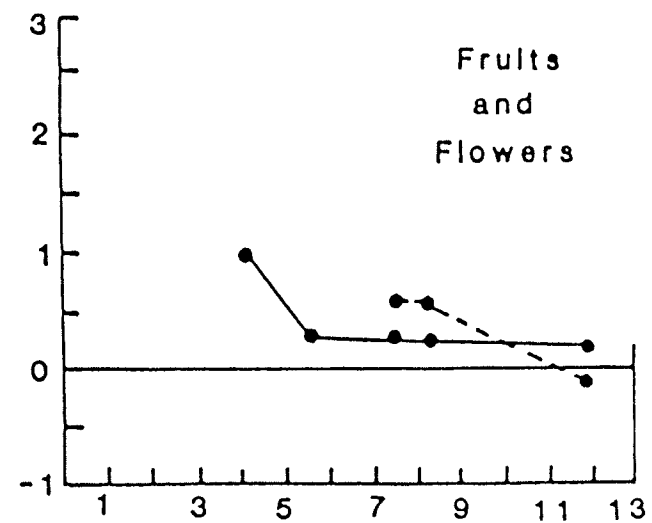
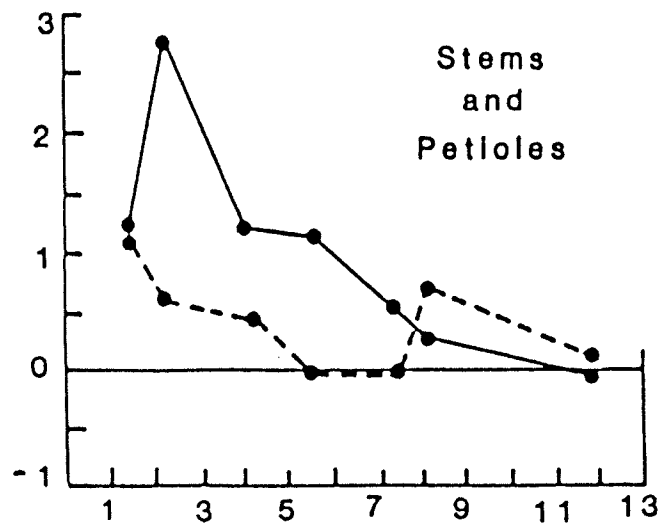
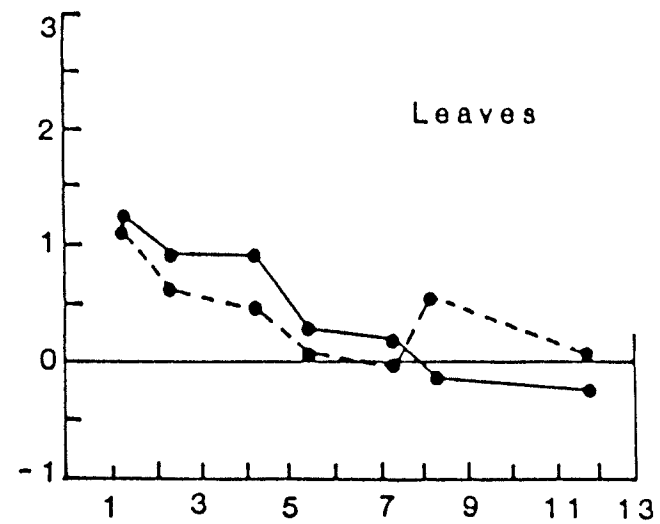
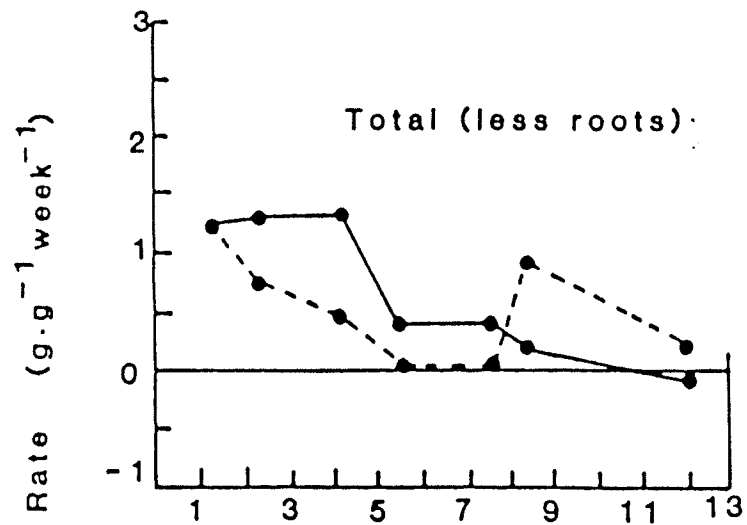
²Spray Date 18/6/85-Flax 14/6/85-Wheat

³0-Represents cotyledonary stage

Figure 19. RGR of mallow growing in a flax field at Manitou,
Manitoba (1985)

Sprayed --

Unsprayed —

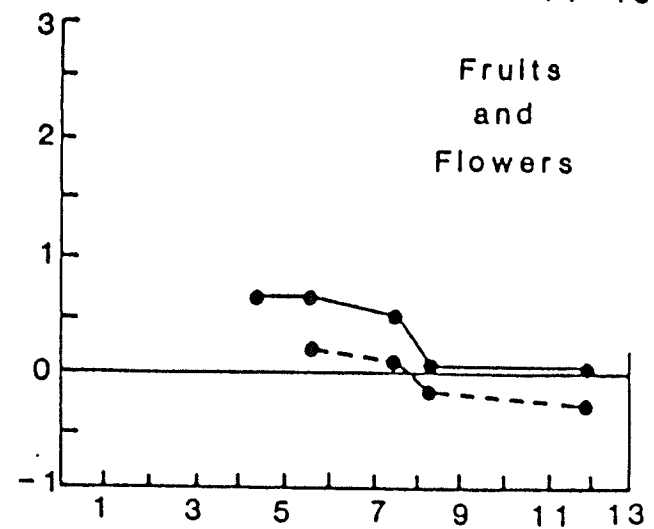
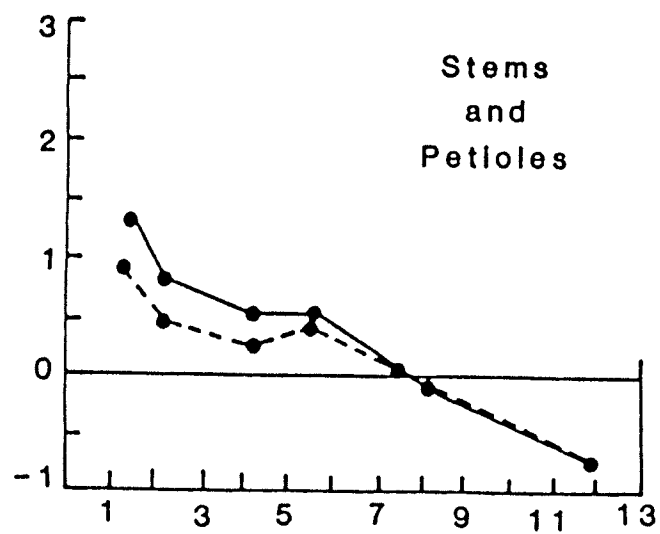
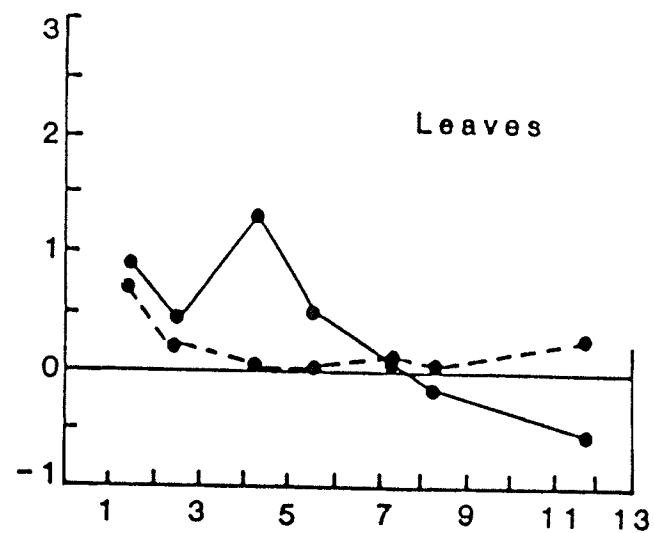
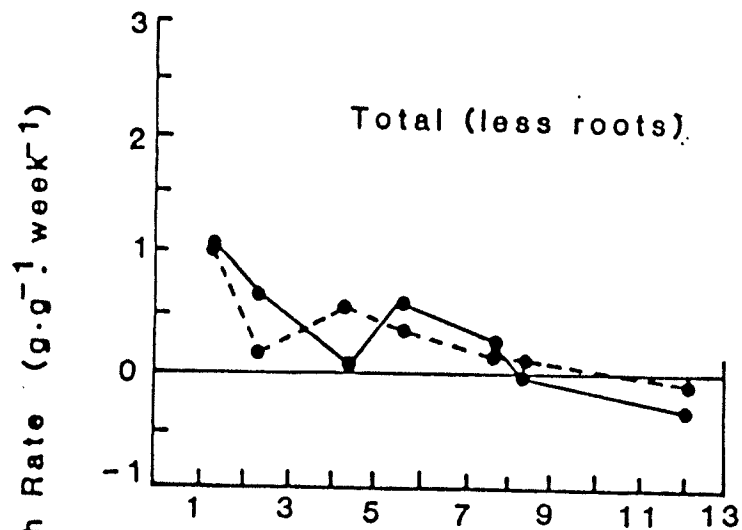


Weeks

Figure 20. RGR of mallow in a wheat field at Manitou, Manitoba
(1985)

Sprayed — —

Unsprayed — —



Weeks

stems of mallow in the flax field (Figure 19) was $2.74 \text{ g g}^{-1} \text{ week}^{-1}$. The maximum RGR of stems and petioles of mallow in the wheat field was considerably lower than in the flax field. However, the RGR of leaves, and RGR of floral structures did not vary greatly from one field to the other. The total accumulation of dry matter by mallow was considerably higher in the flax field than in the wheat field. Mallow plants grown in the flax field had a maximum of 35 leaves per plant; whereas, in the wheat field mallow plants had a maximum of only 8 leaves per plant (Table 8).

Populations of mallow in the two fields also varied considerably (Table 8). Although the population of mallow (Table 8) in the wheat field was more dense than in the flax field the total dry matter accumulated in wheat was much lower than in flax (Table 8). In the flax field mallow produced yields of $78 \text{ g fruits m}^{-2}$ while in the wheat field the fruits weighed 9.5 g m^{-2} .

The LAR of mallow in the flax field remained high until week 9 at which time the LAR decreased (Figure 21a). The LAR of plants in the wheat field dropped sharply after the peak at week 4 (Figure 21b). At week 4 there was increased growth of the wheat and the crop began to tiller.

In the flax field the NAR was initially at $0.013 \text{ g cm}^{-2} \text{ week}^{-1}$ and decreased to $0.0052 \text{ g cm}^{-2} \text{ week}^{-1}$ (Figure 22a). After week 6 the NAR could no longer be calculated due to the lack of a defined relationship between leaf area and

Figure 21 . (a) LAR of mallow growing in a flax field at Manitou
Manitoba

(b) LAR of mallow growing in a wheat field at Manitou,
Manitoba

Sprayed --

Unsprayed —

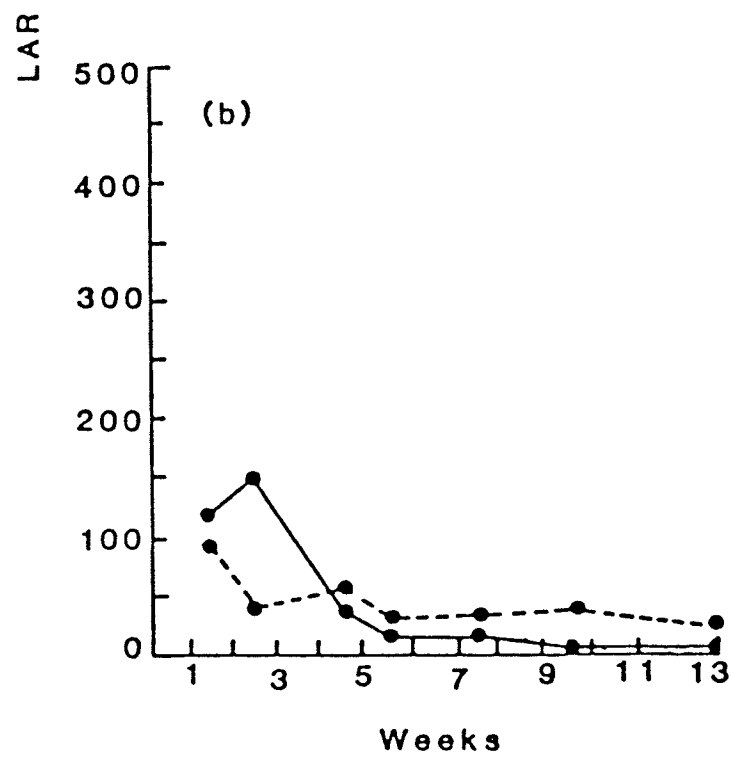
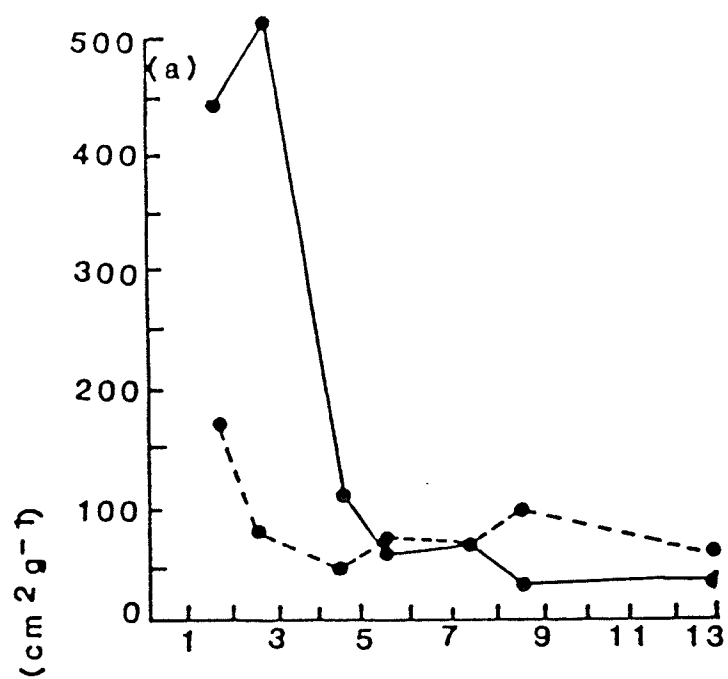
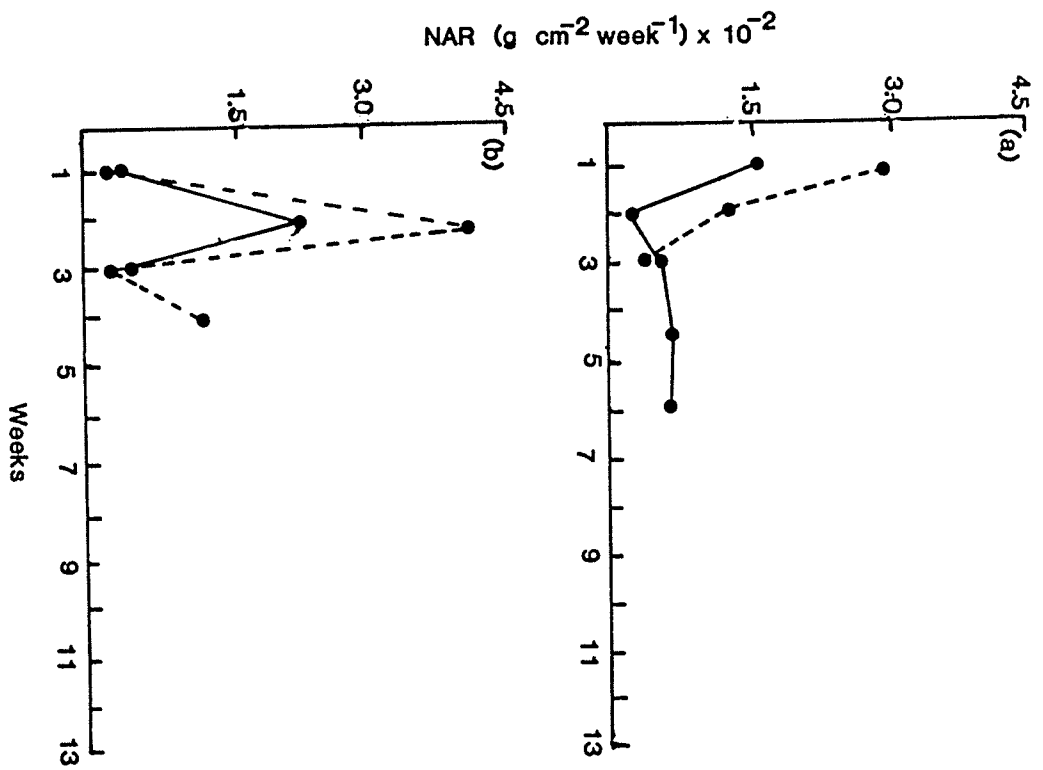


Figure 22. (a) NAR of mallow growing in a flax field at Manitou,
Manitoba (1985)
(b) NAR of mallow growing in a wheat field at Manitou,
Manitoba (1985)

Sprayed--
Unsprayed—



plant weight. In the wheat field the NAR was $0.035 \text{ g cm}^{-2} \text{ week}^{-1}$ initially; it then increased to 0.028 at week 2 and then declined at week 3 (Figure 22b). This was different from the situation in the flax field.

In the flax field the SLA (Table 9) was much higher than the SLA in the wheat field (Table 10). The LAD also was considerably higher in the flax field. The LWR followed a similar growth pattern with initial value being approximately 0.75 in both flax (Table 9) and wheat (Table 10) fields and dropping to less than 0.15 by the last sampling date.

Mallow plants were sprayed with bromoxynil and MCPA in flax and wheat fields 18 June 1985 and 14 June 1985, respectively. In flax, the RGR of all plant parts declined for a 6 to 7 week period after treatment. However, between weeks 7 and 9 there was an increase in the RGR of all plant parts. In addition to this the production of floral structures was initiated at week 7. The RGR of Mallow in the wheat field also declined following the application of the herbicide (Figure 20).

The LAR of sprayed plants progressively declined throughout the sampling period, similar to the unsprayed plants. In the flax field (Figure 22a) the NAR could only be

TABLE 9. Growth Analysis of Mallow, Sprayed and Unsprayed, in a Flax Field at Manitou, Manitoba (1985).

Growth Analysis Parameters				
Sample Weeks	Date ¹	LWR ₁ g g ⁻¹	SLA ₂ cm ² g ⁻¹	LAD cm ² week ⁻¹
Unsprayed				
1	31/5/85	0.75	575	68
2	07/6/85	0.75	695	730
4	21/6/85	0.37	277	4298
5	29/6/85	0.23	253	4690
7	12/7/85	0.24	258	16233
8	19/7/85	0.17	208	9466
9	26/7/85	0.13	255	8202
13	18/8/85	0	0	1825
Sprayed ²				
1	31/5/85	0.21	805	78
2	07/6/85	0.55	135	562
4	21/6/85	0.42	110	2006
5	29/6/85	0.48	133	1340
7	12/7/85	0.50	124	2712
8	19/7/85	0.27	359	3317
9	26/7/85	0.33	228	7971
13	18/8/85	0.23	234	19130

¹Crop Germination 25/5/85

²Spray Date 18/6/86

TABLE 10. Growth Analysis of Mallow, Sprayed and Unsprayed, in a Wheat Field at Manitou, Manitoba (1985).

Growth Analysis Parameters				
Sample Weeks	Date ¹	LWR g g ⁻¹	SLA cm ² g ⁻¹	LAD cm ² week ⁻¹
<u>Unsprayed</u>				
1	31/5/85	-	-	-
2	07/6/85	0.73	155	21
4	21/6/85	0.57	263	862
5	29/6/85	0.41	88	788
7	12/7/85	0.30	32	1031
8	19/7/85	0.31	30	619
9	26/7/85	0.28	11	483
13	18/8/85	0.11	0.2	130
<u>Sprayed²</u>				
1	31/5/85	-	-	-
2	07/6/85	0.48	193	68
4	21/6/85	0.36	134	878
5	29/7/85	0.31	190	576
7	12/7/85	0.15	208	1460
8	19/7/85	0.17	179	781
9	26/7/85	0.20	186	860
13	18/8/85	0.62	41	1156

¹ Crop Germination 27/5/85

² Spray Date 14/6/85

calculated until week 3, therefore there is little information on the effect of herbicides on NAR. In the wheat field (Figure 22b) the NAR increased after the application of the herbicide.

3.2.1.3 Crop Yield

There were no significant differences in the dry weights, yields and densities of either crop between weed-free sprayed and weed-free unsprayed plots. Significant differences occurred between weed-free and weedy plots. There were 23 plants m^{-2} in weedy plots compared to 130 plants m^{-2} (Figure 17) in weed-free plots. The dry weight of flax was 100 g m^{-2} in weedy plots compared to 836 g m^{-2} in weed-free plots. With the removal of mallow plants the final seed yield of the crop was 6.7 g m^{-2} in weedy plots compared to 222.0 g m^{-2} in weed-free plots (Table 11).

In comparing weedy and weedy sprayed plots there was an increase in the density of flax, from 23 to 31 plants m^{-2} (Figure 17). There was an increase in the dry weight of plants from 100 g m^{-2} to 224 g m^{-2} in sprayed plots. The yield of flax in unsprayed plots was 6.7 g m^{-2} compared to 29.3 g m^{-2} in sprayed plots (Table 11).

Table 11. Yield of Flax and Wheat (1985)

Treatment	Unsprayed (g m ⁻²)	Sprayed (g m ⁻²)
<u>Flax</u>		
Weedy	6.7	29.3
Weed-free	222.0	195.4
<u>Wheat</u>		
Weedy	264.3	273.7
Weed-free	334.5	329.7

Least Significant Difference-Flax 3.46

Least Significant Difference-Wheat 2.01

The density of wheat (Figure 18) was 212 plants m^{-2} in weedy plots compared to 269 plants m^{-2} in weed-free plots. The dry weight of the wheat was 586 g m^{-2} in weedy plots and 624 g m^{-2} in weed-free plots. The yield of wheat in weedy plots was 264.3 g m^{-2} compared to 334.5 g m^{-2} in weed-free plots (Table 11).

If weedy plots and weedy sprayed plots are compared there was an increase in the density, dry weight and yield of the wheat. The density increased from 212 to 239 g m^{-2} while the dry weight increased from 586 to 614 g m^{-2} . In the plots the final yield increased from 264.3 g m^{-2} to 266.5 g m^{-2} with the application of bromoxynil and MCPA (Figure 18).

3.2.2 1986

3.2.2.1 Crop Establishment

In 1986, the growth of mallow was studied under field conditions in both flax and wheat at the University of Manitoba Portage Research Station. Germination for both flax and wheat was 5 June 1986, whereas, mallow germinated on 13 June 1986.

A population of 120 flax plants m^{-2} was established in week 0 which increased to 141 plants m^{-2} (Figure 23) in weed-free plots. In weedy plots the density was similar to the weed-free plots with a final density of 146 plants m^{-2} . In the wheat trials a population of 96 plants m^{-2} was

established in week 0 in weed-free plots with the final density being 127 plants m^{-2} (Figure 24). In weedy plots the final population was 120 plants m^{-2} which was similar to the weed-free plots.

3.2.2.2 Growth Analysis

In both flax and wheat trials, the RGR values for mallow were extremely low or negative for most of the season (Figures 25 and 26, respectively). Mallow plants grown in both trials had a maximum of 6 leaves per plant (Table 12). The population in each field remained relatively constant throughout the sampling period (Table 12). There was continual germination, which was offset by death of existing plants throughout the summer.

The LAR of mallow in the flax trial (Figure 27a) and in the wheat trial (Figure 27b) both followed a similar pattern. However, the mallow in the flax trial had a larger LAR than in the wheat trial.

Initially, in the flax experiment the SLA (Table 13) was $153 \text{ cm}^2 \text{ g}^{-1}$, increasing to $347 \text{ cm}^2 \text{ g}^{-1}$ at week 8. In the wheat trial the SLA steadily declined throughout the

Figure 23. (a) Density of flax plants in a field trial infested with mallow (Portage la Prairie, 1986)

(b) Dry weight of flax plants in a field trial infested with mallow (Portage la Prairie, 1986)

Weedy —○

Weedy-sprayed — —○

Weed-free —□

Weed-free sprayed — —□

I Least Significant Difference

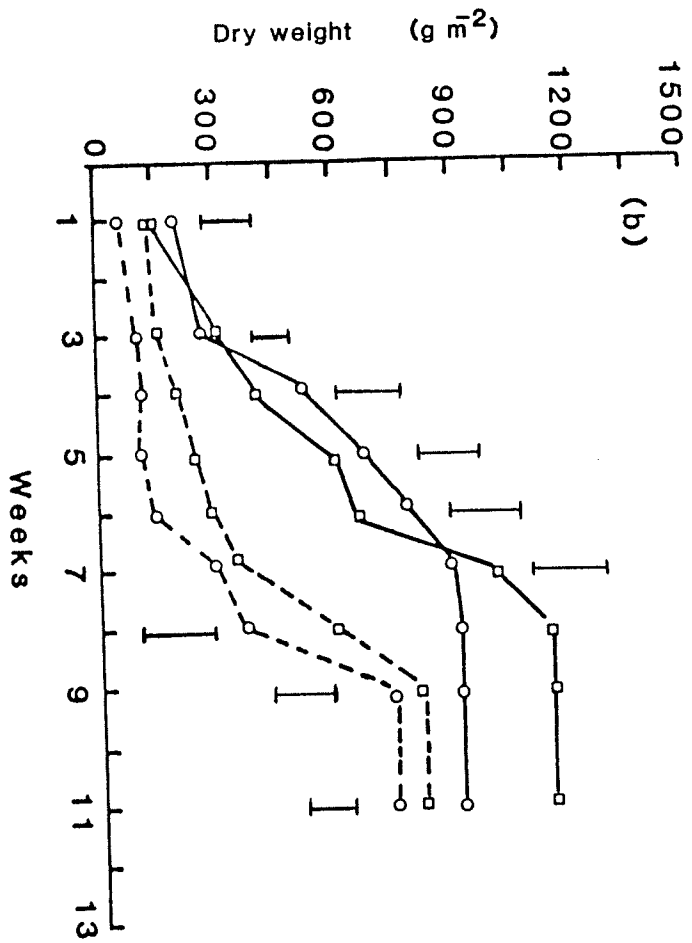
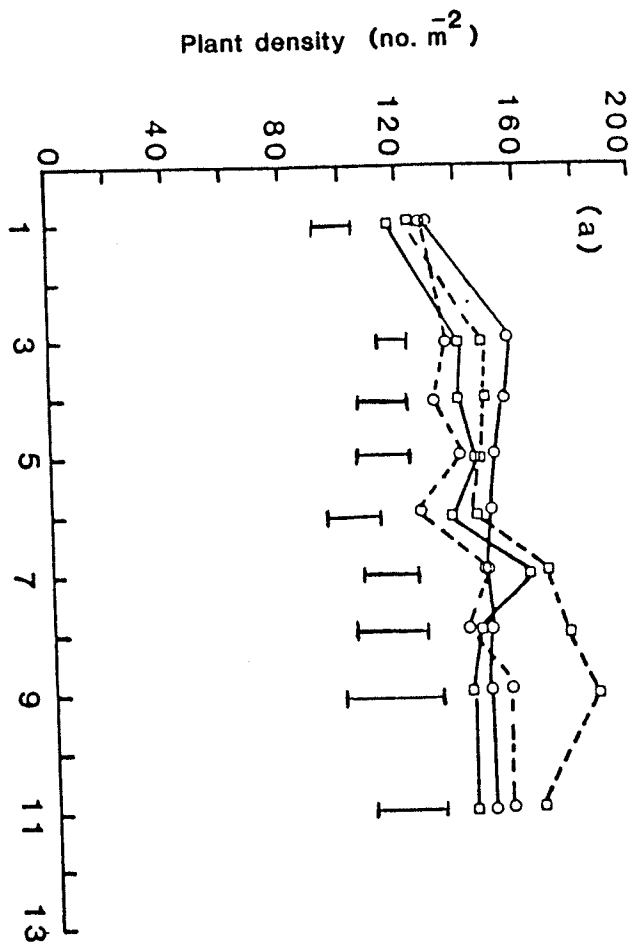


Figure 24. (a) Density of wheat plants in a field trial infested with mallow (Portage la Prairie, 1986)

(b) Dry weight of wheat plants in a field trial infested with mallow (Portage la Prairie, 1986)

Weedy —○

Weedy-sprayed — —○

Weed free —□

Weed free-sprayed — —□

I Least Significant Difference

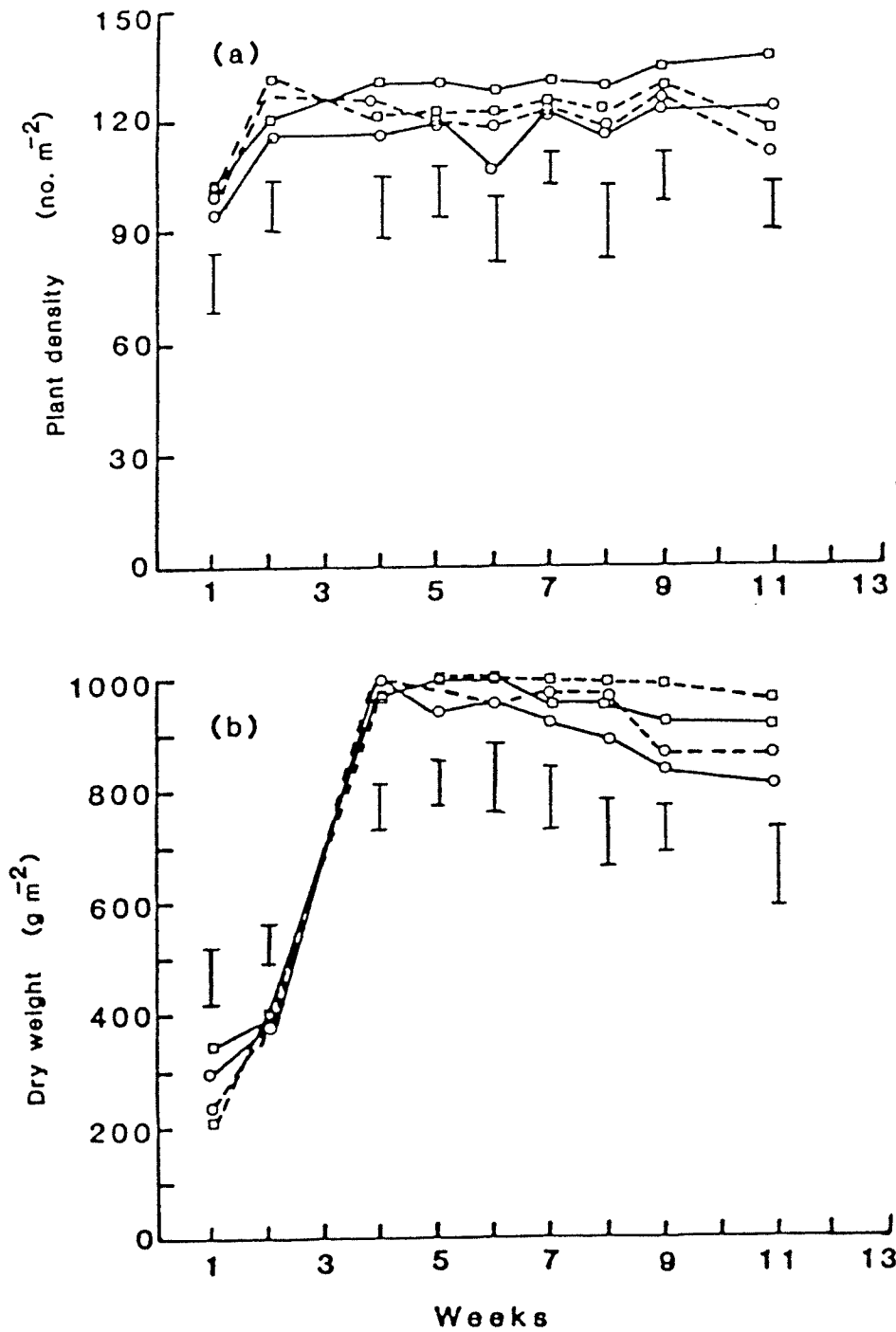


TABLE 12. Density, Growth Stage and Dry Weight of Mallow, Sprayed and Unsprayed, in Field Trials at Portage la Prairie Research Station, Manitoba (1986).

Sample Weeks	Date	Unsprayed			Sprayed ²		
		Density ₋₂ (plants m ⁻²)	Growth Stage (leaves per plant)	Dry Weight (g /m ⁻²)	Density ₋₂ ³ (plants m ⁻²)	Growth Stage (leaves per plant)	Dry Weight (g)
<u>Flax</u>							
1	10/6/86	0 ± 0.0	-	0 ± 0.0	0 ± 0.0	-	0 ± 0.0
3	24/6/86	32 ± 6.1	3 ± 1.3	5.3 ± 1.3	12 ± 4.2	3 ± 1.2	3.5 ± 0.2
4	10/7/86	44 ± 4.3	4 ± 2.6	5.2 ± 0.2	41 ± 7.3	3 ± 1.5	3.9 ± 0.7
5	15/7/86	48 ± 5.8	6 ± 3.1	3.2 ± 0.7	42 ± 8.1	4 ± 2.3	3.7 ± 1.6
6	24/7/86	41 ± 7.1	6 ± 3.0	1.8 ± 0.5	38 ± 6.8	4 ± 3.0	5.3 ± 1.2
7	29/7/86	32 ± 3.4	6 ± 2.2	3.8 ± 0.6	20 ± 1.7	4 ± 2.7	6.3 ± 0.7
8	05/ 8/86	30 ± 9.5	3 ± 1.9	5.4 ± 2.0	17 ± 4.7	3 ± 1.8	6.4 ± 0.9
11	12/8/86	22 ± 8.9	1 ± 0.9	3.7 ± 0.9	12 ± 3.9	5 ± 3.7	6.2 ± 0.9
<u>Wheat</u>							
1	10/6/86	0 ± 0.0	-	0 ± 0.0	0 ± 0.0	-	0 ± 0.0
3	24/6/86	36 ± 4.7	3 ± 1.7	1.9 ± 0.2	9 ± 5.1	3 ± 1.5	3.0 ± 0.1
4	10/7/86	48 ± 5.1	4 ± 2.4	1.3 ± 0.2	30 ± 6.7	4 ± 3.0	3.0 ± 0.1
5	15/7/86	41 ± 6.3	6 ± 4.0	1.2 ± 0.2	27 ± 5.1	4 ± 2.7	3.7 ± 0.1
6	24/7/86	39 ± 4.4	4 ± 3.3	1.2 ± 0.2	19 ± 4.7	3 ± 1.8	5.0 ± 1.0
7	29/7/86	20 ± 5.2	3 ± 2.5	3.2 ± 0.2	18 ± 4.2	3 ± 1.5	5.3 ± 0.1
8	05/ 8/86	19 ± 8.1	3 ± 2.8	4.3 ± 0.1	12 ± 5.0	3 ± 2.0	5.4 ± 0.4
11	12/8/86	21 ± 9.2	2 ± 2.0	4.1 ± 0.3	10 ± 3.6	2 ± 1.0	5.9 ± 0.3

± Standard Deviation

¹Crop Germination 05/6/86

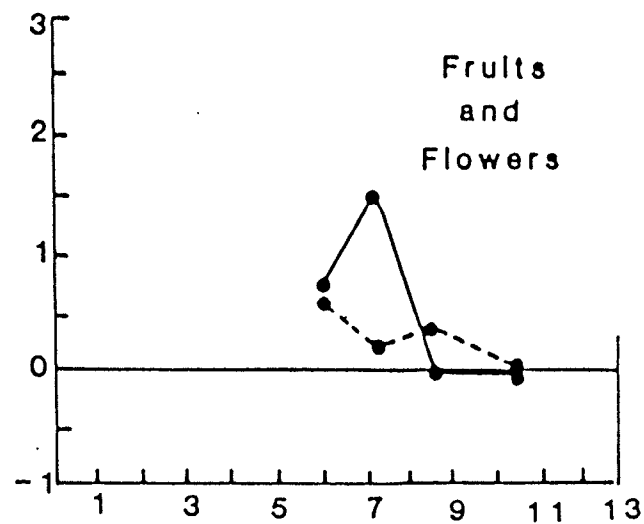
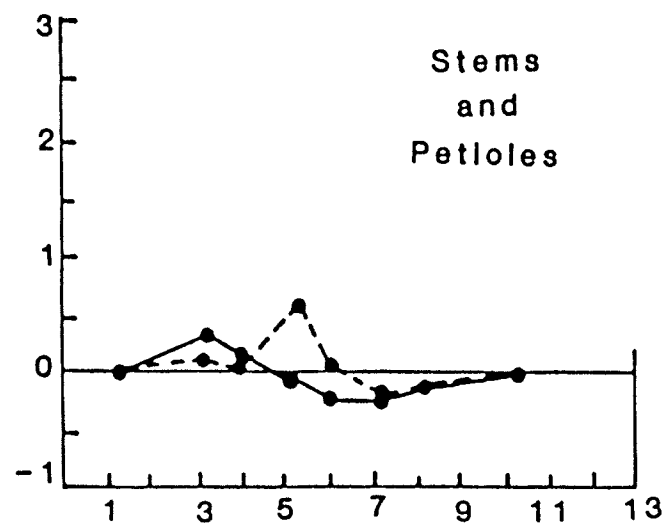
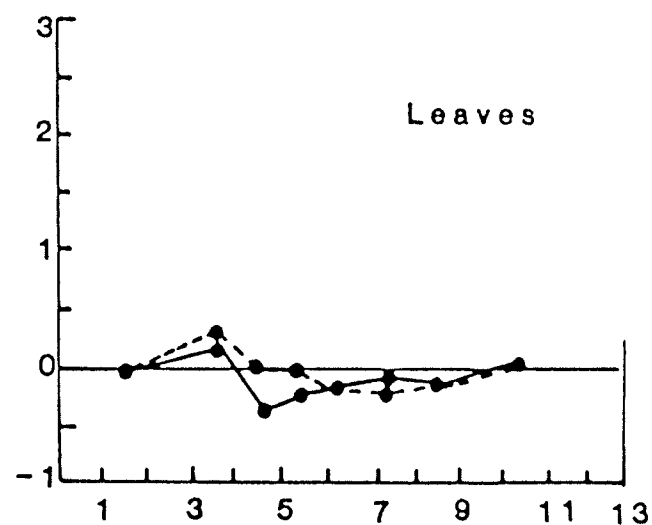
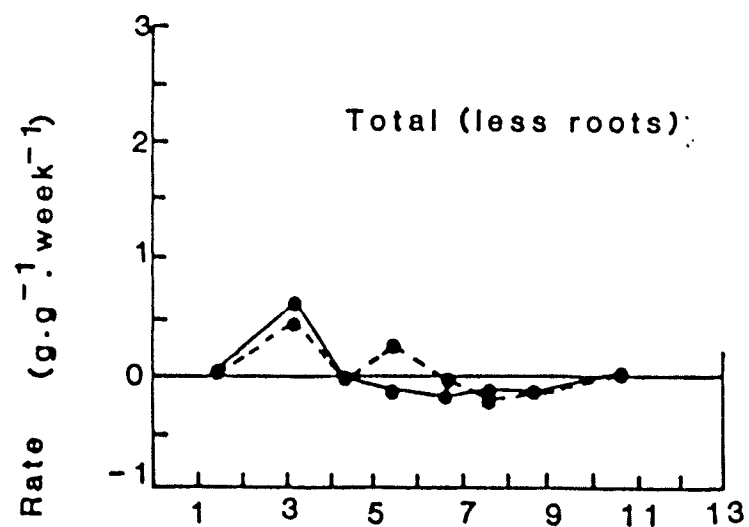
²Spray Date 17/6/86

³Density week 2 Flax-33 Wheat-36

Figure 25. RGR of mallow growing in flax field trials at the Portage
la Prairie Research Station, Manitoba

Sprayed --

Unsprayed —



Weeks

Figure 26. RGR of mallow growing in wheat field trials at the Portage
la Prairie Research Station, Manitoba

Sprayed — —

Unsprayed —

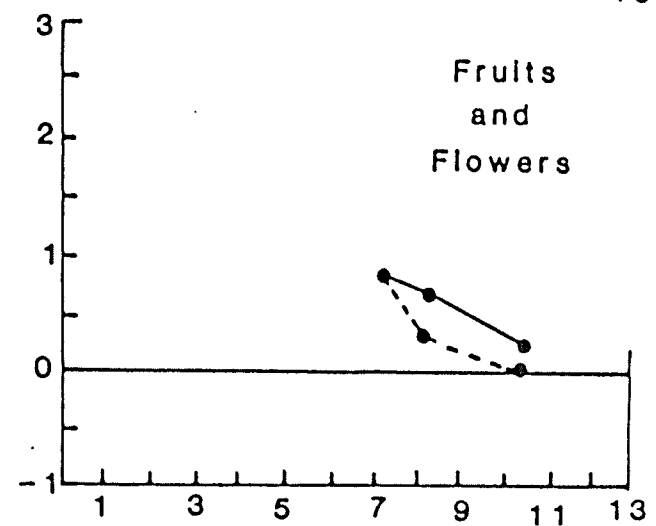
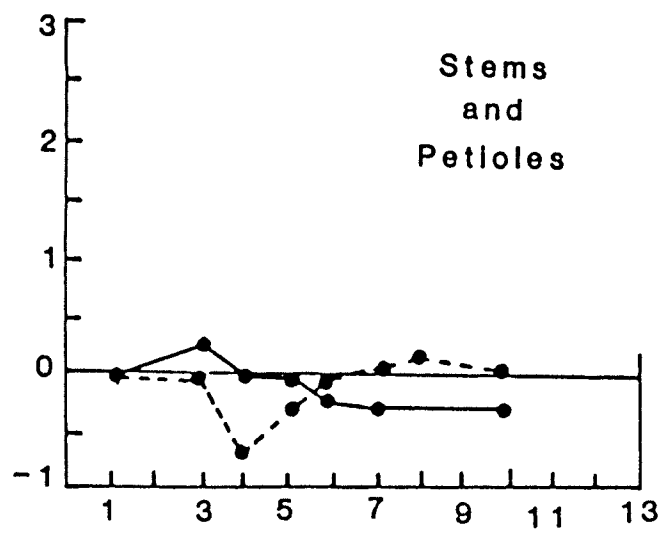
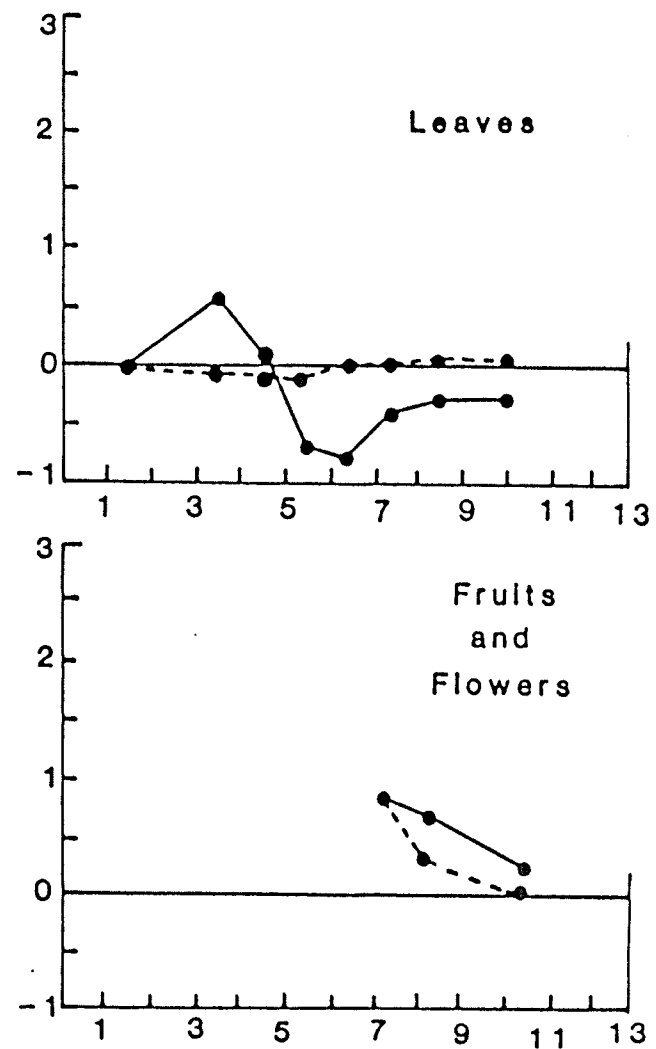
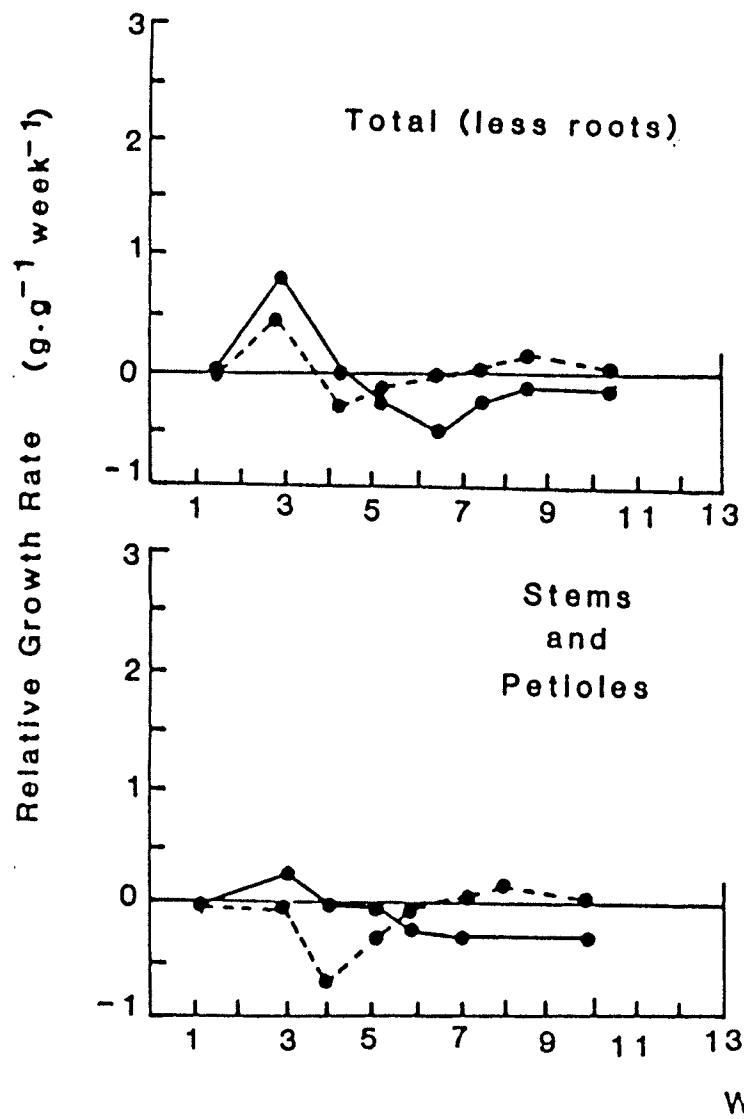


Figure 27. (a) IAR of mallow growing in flax field trials at the
Portage la Prairie Research Station

(b) IAR of mallow growing in wheat field trials at the
Portage la Prairie Research Station, Manitoba

Sprayed --

Unsprayed —

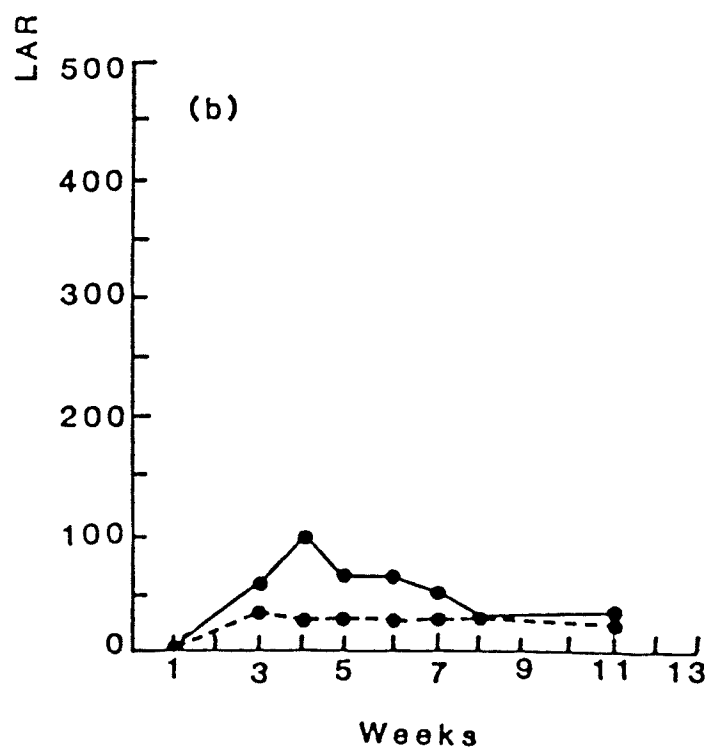
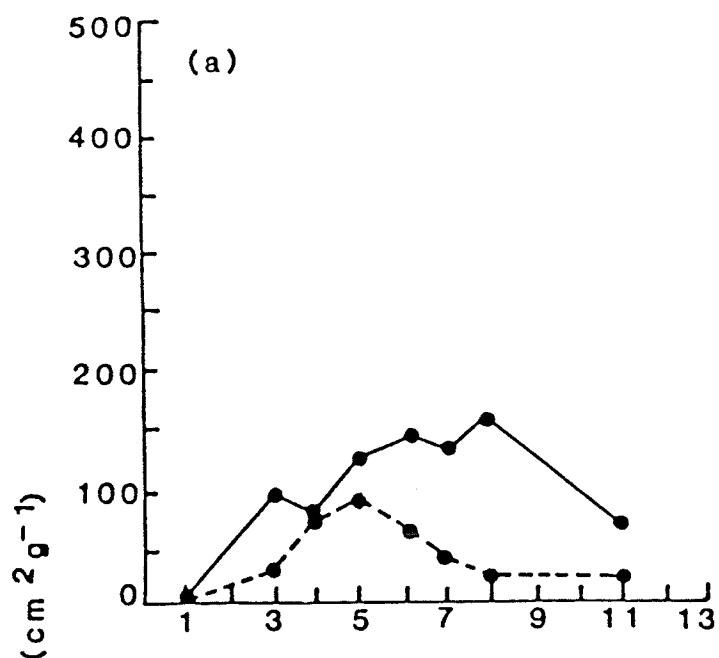


TABLE 13. Growth Analysis of Mallow, Sprayed and Unsprayed, in Flax Field Trials at Portage la Prairie Research Station, Manitoba (1986).

Growth Analysis Parameters				
Sample Weeks	Date ¹	LWR g g ⁻¹	SLA cm ² g ⁻¹	LAD cm ² week ⁻¹
<u>Unsprayed</u>				
1	10/6/86	0.00	0	0
3	24/6/86	0.64	153	157
4	10/7/86	0.66	142	494
5	15/7/86	0.54	207	448
6	24/7/86	0.46	313	348
7	29/7/86	0.44	319	249
8	05/8/86	0.44	347	183
11	12/8/86	0.44	137	282
<u>Sprayed²</u>				
1	10/6/86	0.00	0	0
3	24/6/86	0.50	54	25
4	10/7/86	0.68	117	72
5	15/7/86	0.72	127	99
6	24/7/86	0.73	95	85
7	29/7/86	0.71	57	57
8	05/8/86	0.70	37	38
11	12/8/86	0.70	33	31

¹Crop Germination 05/6/86

²Spray Date 17/6/86

sampling period (Table 14). The LWR (Table 13 and 14) was much higher in the flax plots than in the wheat plots. The LWR in the wheat was approximately the same throughout 1986. The LAD peaked at week 3 in both trials and then continually declined through the summer.

Mallow plants were sprayed with bromoxynil and MCPA in flax and wheat fields on 17 June 1986. The RGR of mallow plants sprayed in the wheat and flax (Figure 25 and 26, respectively) declined one week following the application of the herbicide. At week 5 there was an increase in the RGR of stems and petioles. Production of floral structures was initiated at week 6. This was similar to floral production in the unsprayed plots. The SLA and LAD (Table 13 and 14) were low throughout the summer. In the flax the LWR peaked at week 5, but in the wheat there was a continual decline in the LWR (Table 14).

The maximum number of leaves per plant in both trials was 4 in sprayed plots (Table 12). Densities at week 2 were 29 and 26 mallow plants m^{-2} in flax and wheat plots, respectively. Mallow had two true leaves when the herbicide was applied. The density decreased following the application of bromoxynil and MCPA. However, more seeds germinated and increased the populations to 41 and 30 plants m^{-2} in flax and wheat plots, respectively (Table 12).

TABLE 14. Growth Analysis of Mallow, Sprayed and Unsprayed, in Wheat Field Trials at Portage la Prairie Research Station, Manitoba (1986).

Growth Analysis Parameters				
Sample Weeks	Date ¹	LWR g g ⁻¹	SLA cm ² g ⁻¹	LAD cm ² week ⁻¹
<u>Unsprayed</u>				
1	10/6/86	0.00	0	0
3	24/6/86	0.48	124	77
4	10/7/86	0.37	273	263
5	15/7/86	0.33	201	256
6	24/7/86	0.34	181	166
7	29/7/86	0.39	141	126
8	05/8/86	0.40	97	88
11	12/8/86	0.40	99	209
<u>Sprayed²</u>				
1	10/6/86	0.00	0	0
3	24/6/86	0.60	58	45
4	10/7/86	0.60	49	98
5	15/7/86	0.48	48	88
6	24/7/86	0.40	55	85
7	29/7/86	0.40	63	81
8	05/8/86	0.42	55	70
11	12/8/86	0.42	45	169

¹Crop Germination 05/6/86

²Spray Date 17/6/86

3.2.2.3 Crop Yield

There was a significant decrease of 18% in dry weight of flax plants from 1103 in weed-free plots to 909 g m⁻² in weedy plots (Figure 23). There was no significant decrease in the dry weight of wheat (Figure 24). There were no significant differences in yields between any treatments in 1986 (Table 15).

3.3 Germination Studies

Scarified mallow seeds had a significantly higher percentage of germination than unscarified seeds irrespective of whether stored at -2° C or 20° C. The storage temperature did not appear to affect the percent germination of the mallow (Table 16).

Scarified Seeds

Seeds germinated one and two months after harvest yielded 100% viable seedlings. Seeds germinated 3 and 4 months after harvest yielded 80 and 69% germination, respectively.

Unscarified Seeds

Seeds germinated four and eight weeks after harvest also yielded 100% germination. However, seeds germinated twelve and sixteen weeks after harvest yielded 60 and 54% germination, respectively.

Table 15. Yield of Flax and Wheat (1986)

Treatment	Unsprayed (g m ⁻²)	Sprayed (g m ⁻²)
<u>Flax</u>		
Weedy	102.6	99.0
Weed-free	111.1	110.3
<u>Wheat</u>		
Weedy	212.6	203.7
Weed-free	224.0	199.8

Least Significant Difference-Flax 12.90

Least Significant Difference-Wheat 14.55

TABLE 16. Germination of Mallow Seed.¹

Weeks after harvest	Percent Germination			
	Scarified		Unscarified	
	20 C	-2 C	20 C	-2 C
4	100 ± 0a ²	100 ± 0a	100 ± 0a	100 ± 0a
8	100 ± 0a	100 ± 0a	100 ± 0a	100 ± 0a
12	80 ± 5b	76 ± 7b	69 ± 6c	59 ± 4d
16	69 ± 4c	60 ± 3d	50 ± 3e	54 ± 2de
± Standard Deviation				

¹Seed obtained from pot grown plants (1985)

²Treatments with similar letters are not significantly different from each other, using t-test at the 5% level of significance.

4. Discussion

4.1 Growth Analysis

Growth analysis was carried out with pot plants in the absence of competition. Initially, the dry matter accumulation was slow (Figure 9a and 9b), until week 4 when there was a rapid increase in the dry weight of the plants. Once mallow was established the biomass allocation to the leaves decreased and allocation to reproductive structures increased. Once initiated, reproductive development continued until senescence. During flowering there was a reduction in root dry weight and an increase in the biomass of the reproductive structures. The final fruit yield of mallow was approximately 55% of the total accumulated dry matter in both 1985 and 1986. The results indicate a possible mobilization of root reserves to the reproductive structures during the early stages. Mobilization of root reserves to floral structures has been noted to occur in annual plants (Salisbury and Ross, 1969).

In 1986 the total accumulation of dry matter was four-fold greater than in 1985 (Figures 9a and 9b). This four-fold increase in growth could have resulted from the higher temperatures and/or differences in soil nitrogen. Dry matter accumulation by a plant is proportional to the resource which limits growth (Radosevich and Holt 1984, Gardner Pearce and Mitchell 1985). In 1986 the soil nitrogen level was significantly higher than in 1985 (173 kg

ha⁻¹ and 60 kg ha⁻¹ respectively). Conceivably the higher soil nitrogen in 1986 increased the dry matter accumulation, provided all other resources were present in sufficiency. However, the higher temperature in 1986 may also have resulted in greater dry matter accumulation that year. In 1986, 1179 degreee days had accumulated at plant maturity compared to 993 in 1985 (Figure 4). Further studies on the response of mallow to varying fertility levels and the response of the weed to different temperature regimes should be conducted to verify these hypotheses.

The maximum leaf RGR (Figures 12 and 13) in both 1985 and 1986 exceeded 2.0 g g⁻¹ week⁻¹, similar to the RGR of other competitive weeds associated with arable fields (Grime and Hunt, 1975). One factor apparently contributing to the success of agronomic weeds such as lambsquarters, field bindweed, chickweed and velvetgrass is a high initial RGR (Grime and Hunt, 1975). The data obtained on the RGR of mallow (Figures 12 and 13) indicate that mallow would be competitive under field conditions due to its high RGR in early stages of growth.

The RGRs for each plant part followed a similar integrated growth pattern both in 1985 and 1986, ie. the RGR's all simultaneously declined through the sampling period. Patterson (1982) reported that an integrated pattern of growth is characteristic of most competitive plant species. He also reported that a large initial leaf

area and biomass is indicative of the rapid development of a large canopy.

SLA is a measure of the thickness of leaves on a plant. In 1985 and 1986 the SLA of mallow was high for the first two to three weeks of growth and declined during flowering (Table 7). Thus, initially the leaves were thin and as flowering proceeded, the leaves became progressively thicker. The SLA in 1986 was much lower than in 1985. The degree days accumulated in 1986 were much higher (1179) than in 1985 (993). It is possible that under a higher temperature regime the leaves of mallow are thicker. It is possible that an increase in irradiance may also have contributed to the thicker leaves, however this parameter was not measured. This trend of declining SLA and LAR is different from the data obtained by Flint et al. (1984) and Patterson et al. (1986) on semi-tropical plants in which the SLA and LAR increased with increasing temperature regimes. The LAR of mallow in 1986 also was lower than in 1985 (Figure 11). LAR is a measure of the proportion of the plant engaged in photosynthesis. Thus the higher temperatures of 1986 may have resulted in a lower proportion of the plant being engaged in photosynthesis with a concomitant increase in structural components, ie. stems and petioles.

The NAR (Figures 16a and 16b) could only be calculated for the first six sampling dates due to the nonexponential

- leaf area versus plant weight relationship of mallow which followed. Radford (1967) proposed several formulae for the calculation of NAR for plants with non-linear dry matter-leaf area relationships. In examining these formulae the dry matter-leaf area relationship (Figure 14 and 15) of mallow did not fit any non-linear pattern suggested by Radford (1967). Thus, using conventional formulae, NAR was calculated only for the first six sampling dates, after which leaf drop occurred.

In both 1985 and 1986 NAR followed a similar pattern. Although SLA decreased, indicating an increase in leaf thickness, the NAR remained relatively constant throughout the sampling period. The data indicate that even though leaf thickness increased during the initial stage of reproduction the relative photosynthetic capacity remained constant.

Further knowledge of the plant form can be obtained by examining the shoot/root ratio and the LWR. The high shoot/root ratio (Table 7) of approximately 3.0 indicates that the shoots produced by mallow increased their potential as a competitive weed, not the roots. The total root dry weight (Figure 9a and 9b) of mallow was low in comparing the other plant parts ie. leaves, stems and petioles and the final fruit dry weight. The LWR (Table 7) showed that when the plants were small the leaves constituted a large portion of the above-ground biomass. A large initial leaf area and

biomass had been reported by Patterson (1982) to correspond to rapid development of a large canopy. Rapid development of a large canopy would result in competition between crop and weed for light.

The LAD (Table 7) of mallow was much higher in 1986 than 1985. The LAD of wild proso millet (Patterson et al. 1986) sicklepod and hemp sesbania (Flint et al. 1984) also increased with an increase in the temperature regimes. In both experiments the dry matter accumulation by the plants was significantly increased with increasing temperatures. The increases were attributed to the modification of the LAD. Thus the data indicate that with the higher temperature regime of 1986 the duration of leaf area was greater. It appears that the modification of the LAD of mallow by the increased temperature in 1986, also was partly responsible for the four-fold dry matter accumulation that year (Figure 9b). The higher LAD in 1986 indicates that there was greater light interception by the plants which ultimately caused the higher dry matter accumulation. Gardner et al. (1985) reported that the plants with a higher LAD intercepted more light which ultimately caused an increase in the dry matter accumulation.

Subsequent experiments were carried out to investigate the growth of mallow under competitive situations. In 1985, under field conditions mallow had a higher RGR in the flax (Figure 19) than in the wheat (Figure 20). Since

germination of mallow occurred before the crops it was able to compete aggressively. In 1985 the most significant difference between the two fields was in the RGR of stems and petioles. The RGR was $2.67 \text{ g g}^{-1} \text{ week}^{-1}$ in flax and $1.46 \text{ g g}^{-1} \text{ week}^{-1}$ in wheat. This lower RGR was no doubt caused by the competition with the wheat. In week 4 the wheat began to tiller and at this time the RGR of the mallow decreased. The canopy produced by the wheat undoubtedly resulted in reductions in the RGR, SLA, LAR and NAR of mallow. The flax was almost totally crowded out by mallow, with only 20 flax plants m^{-2} surviving to the last sample date (Figure 17a). As in 1985 under field conditions in 1986 mallow had a higher RGR in the flax trial (Figure 25) than in the wheat trial (Figure 26).

The RGRs of mallow in the field were much lower in 1986 than 1985. Germination of the mallow occurred after the crop had emerged, and the weed had difficulty competing with both crops in 1986. The mallow plants in both wheat and flax in 1986 were small and had thin stems. In 1986, in other experiments at the Portage la Prairie Research Station, flax cv. 'Dufferin' attained a maximum leaf RGR of $1.27 \text{ g g}^{-1} \text{ week}^{-1}$ and wheat cv. 'Benito' $1.29 \text{ g g}^{-1} \text{ week}^{-1}$ (Morrison and Marshall, 1987). These RGRs are significantly higher than those obtained for mallow. Thus the crops were considerably more efficient at biomass accumulation than the weed in 1986. The maximum number of leaves per plant attained in the field was six. In contrast, in 1985 the

maximum number of leaves per plant was 35 in the flax field and 8 in the wheat. Bubar and Morrison (1984) reported that 4 weeks after wheat germinated the irradiance at soil level was decreased to approximately 60 watts m^{-2} from 220 watts m^{-2} . This rapid canopy production in wheat indicates that weeds must be established prior to week 4 to compete effectively. The poor growth of mallow relative to that of the crops was undoubtedly due in part to temporal differences in emergence and establishment of the weed compared to the crop.

In 1985, in the field experiments the SLA indicated that mallow leaves initially were thin. Once the plants were well established the leaf thickness increased, indicated by the decreasing SLA. These results are comparable to those obtained in the pot experiments. However, the SLA of mallow plants in the wheat field was much lower than in the flax field. In 1986, the SLA (Table 15) was low throughout the sampling period. In the 1986 wheat trial there was a continual decrease in the SLA and a low, constant LAR throughout the summer. The LAR of mallow initially had a high value in the flax field and decreased throughout the 1985 growth period. It is possible to conclude from this that initially a high proportion of the plant was engaged in photosynthesis during the establishment and at the initiation of flowering the proportion of the plant engaged in photosynthesis declined. The production of the floral structures rather than photosynthetic apparatus predominated

after week 4. The LAR of mallow in 1986 initially was $0 \text{ cm}^2 \text{ g}^{-1}$ due to the lack of plants in the field at this time. The low LAR was due to the slow germination and ultimate competition with the crop compared to the higher LAR in 1985. In the wheat field the LAR remained approximately $65 \text{ cm}^2 \text{ g}^{-1}$ throughout the sampling period, which no doubt resulted from shading of the weed.

NAR is a measure which is closely connected with the photosynthetic activity of the leaves. The NAR of mallow in the flax field in 1985 (Figure 22a) followed a similar pattern as the NAR for pot grown mallow (Figure 16a and 16b) which would indicate that competition was not a major factor in mallow growth in the flax field. However, in the 1985 wheat (Figure 22b) the NAR was much higher until week 3 than in the flax. This would indicate that growth of the wheat decreased the photosynthetic capacity of the mallow through shading after 3 weeks. The NAR of soybean was also decreased by competition with a grassy plant (Patterson et al. 1984). Thus it appears that a crop such as wheat that produces a large canopy would decrease the photosynthetic capacity of mallow through competition.

The LAD is the duration of leaf area over time. In 1985, at week 4 the LAD of mallow was $4398 \text{ cm}^2 \text{ week}^{-1}$ in the flax and $862 \text{ cm}^2 \text{ week}^{-1}$ in the wheat. The shading of mallow by the wheat canopy caused a decrease in the LAD and thus a decrease in the dry matter accumulation over the sampling

period. In 1986, the LAD was $494 \text{ cm}^2 \text{ week}^{-1}$ in the flax trial and $263 \text{ cm}^2 \text{ week}^{-1}$ in the wheat. The modification of the LAD caused by competition with the crop in 1986 partly explains the reduced dry matter accumulation (Table 12).

In 1985, mallow fruit yield was 78 g m^{-2} in the flax and 9.5 g m^{-2} in the wheat. These high yields can be attributed to the long flowering period of eight weeks. Mallow flowered until the end of senescence; however, flowers produced late in the season did not produce viable seeds. In 1986, the dry matter accumulation of fruits was considerably less. A final fruit yield of 3 g m^{-2} was attained in the flax trial while in the wheat trial the final yield was 4 g m^{-2} . Even under the aggressive competition experienced in 1986, mallow was able to produce a large fruit yield compared to the size of the plant.

This is one of the few competitive growth analysis studies carried out under natural field conditions. Until recently growth analysis techniques have been used to analyze the growth of crop species under various treatments (Noggle and Fritz 1976, Fitter and Hay 1981, Hunt 1982, Radosevich and Holt 1984). Mathematical growth analysis is a convenient means of examining the dry matter production and leaf area expansion which are important in determining the potential competitiveness of a weed (Patterson, 1982). Grime and Hunt (1975) examined the RGR of several weed species with respect to their growth habit and distribution.

Patterson et al. (1979, 1984, 1986) and Flint et al. (1984) have shown the usefulness of growth analysis in the study of weed ecology. These investigations have led to estimations of the potential growth and distribution of semi-tropical weed species. Growth analysis as a tool for the study of weeds, is relatively new and much work is required for an adequate understanding of the growth and distribution of weed species. Although mathematical growth analysis is a valuable technique to provide information on the relative competition of plants, there are limitations. Growth analysis is a destructive sampling technique, thus many large samples are required to obtain a representative sample for analysis. It has been noted that interpretation of the results must be carefully reached due to the interchange of dry matter between different plant parts (Radford, 1967). Certain assumptions must be made to be able to calculate growth analysis formulae, thus inappropriate use of the formulae may occur. Large errors in the interpretation of the NAR may occur if the leaf area-dry weight relationship is non-linear. It is necessary to examine the relationships between time, leaf area and dry weight prior to calculating growth parameters.

Using such parameters it is possible to estimate the potential seriousness of a weed. Under field conditions it is currently difficult to predict the potential competitiveness of mallow due to differences between 1985 and 1986 studies. It is certain however, that under natural

field conditions, such as occurred at Manitou, mallow that establishes before the crop will compete aggressively with the crop.

4.2 Control of Mallow

Following the application of the herbicide in the flax field and wheat fields the RGR of mallow decreased for all parts both years. At week 7 in 1985 there was a large increase in the RGR of mallow in the flax field. At this point the weed branched and the dry weight increased sharply. The herbicide killed the apical meristem which initiated the growth of lateral buds. The RGR of mallow in the wheat field did not increase as in the flax field (Figures 19 and 20). This lack of recovery in the wheat field is no doubt due to the competition with the wheat as discussed earlier. There was no significant decrease in the amount of the plant which was engaged in photosynthesis due to the effects of the herbicide. The LWR (Table 9 and 10) indicated that the leaf dry weight was decreased from the herbicide. Although the leaves were killed by the herbicide the stems were not affected. This increase in leaf RGR shows the recuperative ability of a herbicide-stressed plant. Recovery from herbicide injury has not been studied extensively.

At the time of spraying in Manitou and Portage la Prairie the temperature was 16° C. Friesen and Dew (1966) reported

that the phytotoxic effects of bromoxynil were altered by temperature changes. Phytotoxicity of bromoxynil was noticeably less when temperatures were 24-13° C than at 18-7° C (Friesen and Dew, 1966). This decreased control of buckwheat was also accentuated when moisture was limited. Another report, by Nalewaja and Skrzypczak (1986) indicated that a high temperature of 30° C increased the phytotoxic effect of bromoxynil on wild mustard and redroot pigweed. Plants under low temperature conditions were prone to recovery from the herbicide injury. Thus it is possible that the recovery observed was due to decreased phytotoxicity of bromoxynil at the low temperature of 16° C.

The density of mallow was decreased by the herbicide (Table 8 and 12). Germination occurred in the flax field following herbicide application in 1985 and increased the population from 28 to 52 plants m⁻². The SLA of mallow was much lower in the sprayed plots. Thus the data indicate that the new leaves of mallow are thicker after herbicide application. The LAR of sprayed mallow remained approximately the same as the LAR of unsprayed mallow. This indicates that the amount of the plant engaged in photosynthesis was not affected by the application of the herbicide in 1985. However, in 1986 in the flax trial the proportion of the plant engaged in photosynthesis was decreased by the application of the herbicide (Figure 27). Plants in 1986 trials were in the cotyledonary stage when the herbicide was applied, thus the LAR values obtained were

directly related to the decrease in the density (Table 12).

4.3 Competition Results

There was no significant difference between unsprayed weed-free and weed-free plots sprayed with bromoxynil and MCPA. In experiments at Manitou there was an 82% increase (Figure 17a) in the density of flax plants with the removal of mallow from the plots. The flax plants that survived were quite thin and poorly developed, thus with handweeding of these plots there was an increase of 89% in the dry weight. Many of the flax plants in the weedy plots attained a height comparable to those in weed-free plots. The flax plants in the weedy plots did not have leaves on the lower portions of the stems. This lack of leaves appears to have been due to shading by the mallow. The flax in the weedy plots did not stool at any point in the growing period. With the removal of mallow there was an increase of 97% in the final seed yield of the flax. In weedy plots flowers were poorly developed and many never properly opened. The use of bromoxynil and MCPA increased the density, dry weight and yield of the flax in weedy plots (6%, 8% and 12% respectively).

Cow cockle at 400 plants m^{-2} reduced the seed production of flax by 61% (Alex, 1968). Flax suffered a yield loss of 74% with 75 Tartary buckwheat plants m^{-2} (St Remy and O'Sullivan, 1986). With 39 mallow plants m^{-2} the yield of

flax was decreased 97%. From this study it can be concluded that mallow competes more aggressively with flax than either cow cockle or Tartary buckwheat. The data indicate that this aggressive competition is due to the large canopy produced by the weed. Grain yields were significantly reduced as the population of mallow increased (Table 5) (Mortenson, 1986). Mortenson reported that the yield of wheat was decreased 23% with competition from 32 mallow plants m^{-2} . In this study the yield of wheat was decreased 19% by the presence of 39 mallow plants m^{-2} , similar to Mortenson's results.

The use of bromoxynil and MCPA increased the density, dry weight and yield of the wheat crop (10%, 8% and 4% respectively). Thus the herbicide slowed the growth of the weed allowing the wheat to advance slightly before the weeds resumed growth. This allowed the crop to produce a slightly higher density, dry weight and yield than unsprayed plots. Thus, to control mallow an effective herbicide and a competitive crop would decrease the growth of the weed.

In 1986, there was no significant decrease in density and yield between the plots of flax, or within wheat trials (Figure 23a, 24a, and 24b). This appears to be due to the germination and establishment of the crop prior to the germination of mallow.

Under natural field conditions mallow aggressively competes with the crop. The canopy production by mallow can

be decreased through the use of herbicides. It is important to control mallow in the early stages of growth prior to growth of the canopy. Adequate information on the competition of mallow is lacking. Replacement series and time of removal studies would provide more information on this troublesome weed.

4.4 Germination Studies

Initially mallow seeds germinated 100% up to eight weeks after maturity (Table 15). The results indicate that the storage conditions with respect to temperature had no effect on the germination of mallow. However, scarification of the seed coat significantly increased the germination rate of mallow over unscarified seed. The data indicate that mallow enters a second dormancy eight weeks following maturity. The seeds of mallow may reach maturity anywhere from July to September. Eight weeks following maturity a killing frost in the fall may be experienced. Therefore it seems reasonable that this is a mechanism of preventing the germination of seeds at inappropriate times of the year. Scarified seeds had a greater germination rate over unscarified seeds. Therefore it appears that a secondary dormancy is attained partly by an increased scarification of the seed coat, preventing entry of water to the seed to allow germination, as suggested by Hunter (1985b). Germination prior to frost may be a means of allowing plants

to overwinter, since it has been observed (Jaques, 1959) that mallow is a biennial weed. Germination studies conducted were carried out under a constant temperature regime. The germination requirements of mallow have never been recorded, ie. light temperature, moisture and periodicity. This experiment only examined the germination over time with respect to secondary dormancy.

No other studies have been carried out on mallow with respect to dormancy but experiments have been carried out on small flowered mallow (Sumner and Cobb 1967). Due to the similarity between the species it seems conceivable that the dormancy mechanisms may be similar. Sumner and Cobb (1967) suggested that even after the seed coat is mechanically removed endogenous inhibitors prevent germination of small flowered mallow. This factor may also be present in mallow due to the low germination rate of the scarified seeds (Table 15).

Bibliography

Alex, J.F. 1968. Competition between linseed flax and Saponaria vaccaria. Can. J. Plant Sci. 48:139-147.

Alex, J.F. 1970. Competition of Saponaria vaccaria and Sinapsis arvensis in wheat. Can. J. Plant Sci. 50:379-388.

Annis, B., G. Tamaki and R.E. Berry. 1981. Seasonal occurrence of wild secondary hosts of the green peach aphid, Myzus persicae (Sulzer), in agricultural systems in the Yakima Valley. Environ. Entomol. 10:307-312.

Anonymous. 1950. Nebraska Weeds. Publication Division of Noxious Weeds. Bulletin 101 Lincoln Nebraska. pp. 140-141.

Anonymous. 1981. Weeds of North Central States. North Central Research Publication No. 281. University of Illinois. Agricultural Experimental Station.

Anonymous. 1982. 1981 Manitoba Seed Grain Survey. Manitoba Department of Agriculture. Manitoba.

Anonymous. 1986. First bioherbicide controls round-leaf mallow. Grainnews. September 8, 1986. p. 13.

Anonymous. 1987. Research Bulletin: A Bioherbicide to Control Round-Leaved Mallow. PhliomBios Printed in Canada Marcomm Communications.

Bubar, C.J. and I.N. Morrison. 1984. Growth responses of green and yellow foxtail (Setaria viridis and S. lutescens) to shade. Weed Science. 32:774-780.

Byrne, J.M. 1973. The root apex of Malva sylvestris III. Lateral root development and the quiescent center. Amer. J. Bot. 60(7):657-662.

Byrne, J.M. and C. Heimsch. 1970. The root apex of Malva sylvestris I. Structural development. Amer. J. Bot. 57(10):1170-1178.

Carlson, K.D. and C.V. Eberlein. 1983. Growth and development of dwarf mallow (Abstract). NCWCC Proceedings. vol. 38. p. 50.

Dimetry, N.Z. 1971. Studies on the host preference of the cotton seed bug Oxycarenus hyalinipennis Costa (Lygaeidae: Hemiptera) (Abstract). Zeitschrift für Angewandte Entomologie. 68(1):63-67.

Donaghy, D.I. and A.R.W. Sturko. 1983(a). Control of roundleaved mallow in wheat. ECW report. p. 642.

- Donaghy, D.I. and A.R.W. Sturko. 1983(b). Control of roundleaved mallow in wheat. ECW report. pp. 642-643.
- Fitter, A.H. and R.K.M. Hay. 1981. Environmental Physiology of Plants. Academic Press. New York. pp. 8-12.
- Flint, E., D.T. Patterson, D.A. Mortenson, G.H. Rieckers and J.L. Beyers. 1984. Temperature effects on growth and leaf production in three weed species. Weed Science 32:655-663.
- Friesen, H.A. and D.A. Dew. 1966. The influence of temperature and soil moisture on the phytotoxicity of dicamba, picloram, bromoxynil, and 2,4-D Ester. Can. J. Plant Sci. 46:653-660.
- Gardner, F.P., R.B. Pearce and R.L. Mitchell. 1985. Physiology of Crop Plants. 1st ed. Iowa State University Press.
- Georgia, A. 1933. Manuel of Weeds. MacMillan Company. New York. pp. 280-281.
- Grime J.P. and R. Hunt. 1975. Relative growth-rate: Its range and adaptive significance in a local flora. J. Ecol. 63:393-422.
- Gruenhagen, R.D. and J.D. Nalewaja. 1969. Competition between flax and wild buckwheat. Weed Science 9:380-384.
- Hunt, R. 1982. Plant Growth Curves: A Functional Approach to Plant Growth Analysis. University Park Press. Baltimore. pp. 1-248.
- Hunter, J.H. 1982(a). Chemical control of round-leaved mallow. ECW report. p. 577.
- Hunter, J.H. 1982(b). Chemical control of round-leaf mallow. ECW report. p. 578.
- Hunter, J.H. 1983(a). Control of roundleaf mallow with 2,4-D ester at different leaf stages. ECW report. p. 643.
- Hunter, J.H. 1983(b). Control of roundleaf mallow with herbicides registered on wheat. ECW Report. pp. 643-644.
- Hunter, J.H. 1985(a). How to prevent grain storage problems caused by round-leaved mallow. Grainnews August 1985. pp. 14, 21.
- Hunter, J.H. 1985(b). Round-leaved mallow: A new problem weed. Manitoba Agricultur Bulletin. 1985.
- Jaques, H.E. 1959. How to Know the Weeds. Wm. Brown Company Publishers Dubuque Iowa.

Jensen, K.I. 1976. Weed control in sweet onions (Abstract). Agriculture Canada Annual Research Report. Kentville Nova Scotia.

Johnson, E.F. and D.I. Donaghy. Kochia and round-leaved mallow control in wheat. ECW report. p. 320.

Kaskiw, E.H. 1985. Assess the efficacy of estaprop on round leaf Mallow. ECW report. p. 183.

Kivilaan, A. and R.S. Bandurski. 1981. The one hundred-year period for Dr. Beal's seed viability experiment. Amer. J. Bot. 68(9):1290-1292.

Landis, B.J., D.M. Powell, and L. Fox. 1972. Overwintering and winter dispersal of the potato aphid (Macrosiphum euphorbiae: Hem., Hom., Aphididae) in eastern Washington. Environ. Entomol. 1:68-71.

Looman, J. and K.F. Best. 1979. Budd's Flora of the Prairie Provinces. Research Branch Agriculture Canada Publication 1662 Ca. Hull. pp. 520-522.

Milthorpe, F.L. and J. Moorby. 1974. An Introduction to Crop Physiology. Cambridge University Press. Great Britain. pp. 152-157.

Morrison, I.N. and G. Marshall. 1987. Unpublished data.

Mortenson, K. 1986. Personal Communication. Agriculture Canada Regina Research Station.

Mortenson, K. 1987. Personal Communication. Agriculture Canada Regina Research Station.

Nalewaja, J.D. and G. Skrzypczak. 1985. Environment and bromoxynil phytotoxicity. Weed Science 34:101-105.

Noggle, G.R. and G.J. Fritz. 1976. Introductory Plant Physiology. Prentice-Hall, Inc. New Jersey. pp. 586-588.

Pammel. 1913. The Weed Flora of Iowa. Geological Survey Bulletin 4. Iowa.

Patterson, D.T. 1979. The effects of shading on the growth and photosynthetic capacity of itchgrass (Rottboellia exaltata) Weed Science 27(5):549-553.

Patterson, D.T., E.P. Flint and J.L. Beyers. 1984. Effects of CO₂ enrichment on competition between a C₄ weed and a C₃ crop. Weed Science. 32:101-105.

Patterson, D.T., A.E. Russell, D.A. Mortenson, R.D. Coffin and E.P. Flint. 1986. Effects of temperature and photoperiod

on Texas panicum (Panicum texanum) and wild proso millet (Panicum miliaceum). Weed Science. 34:876-882.

Pavlychenko, T.K. 1937. Quantitative study of the entire root systems of weed and crop plants under field conditions. Ecology 18:62-79.

Pavlychenko, T.K. and J.B. Harrington. 1934. Competitive efficiency of weeds and cereal crops. Can. J. Research 10:77-94.

Pavlychenko, T.K. and J.B. Harrington. 1935. Root development of weeds and crops in competition under dry farming. Scientific Agriculture 16:151-160.

Pyasyatskene, A.A. 1978. Phenology and growth of plants of the Malvaceae family in the Lithuanian-SSR USSR Part I Annual species of mallow (Abstract). Inst. Bot., Acad. Sci. Lith. SSR, Vilnius USSR.

Radford, P.J. 1967. Growth analysis formulae - Their use and abuse. Crop Science. 7:171-175.

Radosevich, S.R. and J.S. Holt. 1984. Weed Ecology: Implications for Vegetation Management. A Wiley-Interscience Publication. USA. pp. 178-193.

Robins, W.W., M.K. Bellue and W.S. Ball. 1951. Weeds of California. California State Dept. of Agriculture. p. 297.

Rother, W. 1985. Round leaf mallow control with glean, DPX T6376, DPX M6316 and DPX E8698. ECW report. p. 720.

Salisbury, F.B. and C. Ross. 1969. Plant Physiology. Wadsworth Publishing Co. Belmont California.

St. Remy, E. and P.A. O'Sullivan. 1986. Duration of tartary buckwheat (Fagopyrum tataricum) interference in several crops. Weed Science 34:281-286.

Sumner, D.C. and R.D. Cobb. 1967. Germination characteristics of cheeseweed (Malva parviflora L.) Seeds. Agronomy Journal 59:207-208.

Tamaki, G. and L. Fox. 1982. Weed species hosting viruliferous green peach aphids, vector of beet western yellow virus. Environ. Entomol. 11:115-117.

Tamaki, G., L. Fox and R.L. Chauvin. 1980. Green peach aphid: orchard weeds are host of fundatrix. Environ. Entomol. 9:62-66.

Thomas, A.G. and R.F. Wise. 1982. The 1981 Weed Survey of Cultivated Land in Manitoba. Weed Survey Series Publ. 82-1.

Agriculture Canada Regina and Manitoba Department of Agriculture Production Division.

Thomas, A.G. and R.F. Wise. 1983. Weed Survey of Saskatchewan Cereal and Oilseed Crops from 1976-1979. Weed Survey Series Publ. 83-6. Agriculture Canada Regina.

Thomas, A.G. and R.F. Wise. 1984. Weed Survey of Manitoba Cereal and Oilseed Crops 1978, 1979 and 1981. Weed Survey Series Publ. 84-1. Agriculture Canada Regina and Manitoba Department of Agriculture.

Thomas, A.G. and R.F. Wise. 1985. Dew's Alberta Weed Survey 1973- 1977. Weed Survey Series Publ. 85-3. Agriculture Canada Regina.

Thomas, A.G. and R.F. Wise. 1986. Weed Survey of Saskatchewan Sunflower Fields 1985. Weed Survey Series Publ. 86-1. Agriculture Canada Regina.

Todd, B. 1985. Personnal Communication. Manitoba Department of Agriculture.

Wareing, P.F. and I.D.J. Phillips. 1970. The Control of Growth and Differentiation in Plants. 2nd Edition. Pergamon Press Toronto. pp. 17-20.

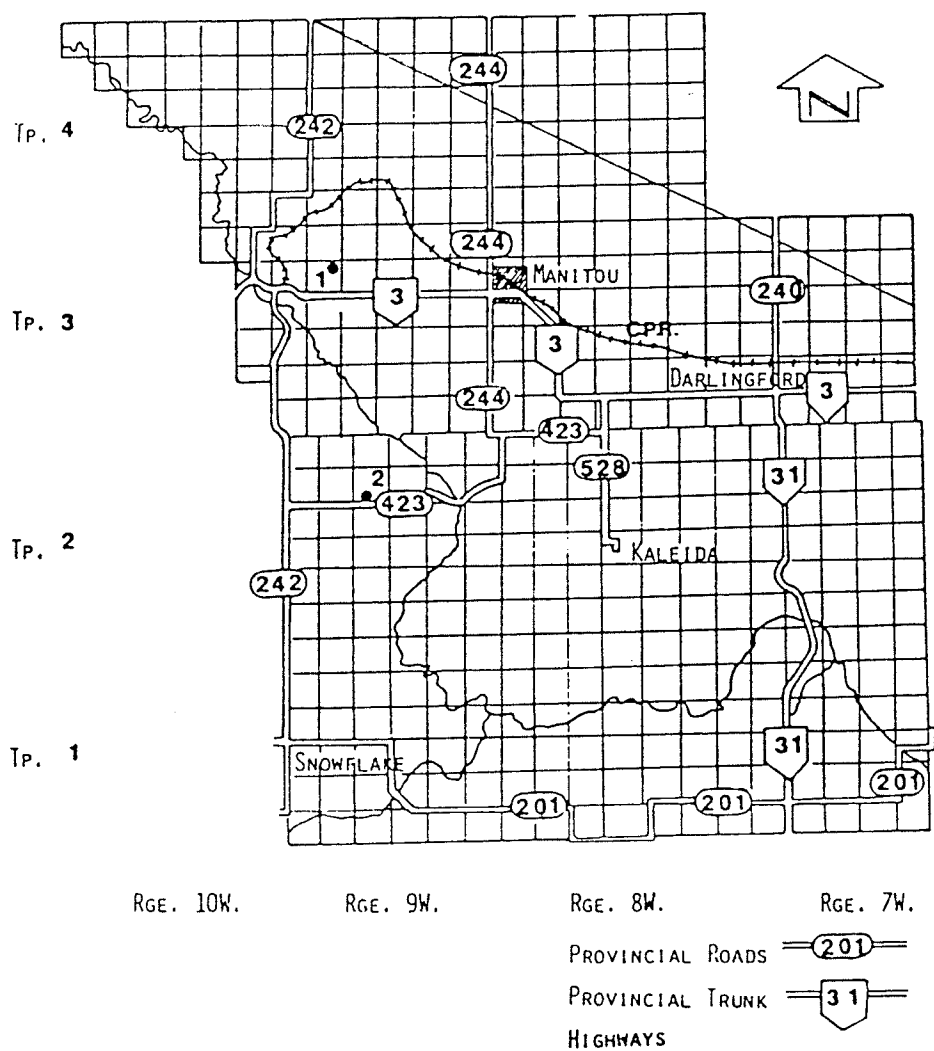
Wareing, P.F. and I.D.J. Phillips. 1981. Growth Differentiation in Plants. 3rd Edition. Pergamon Press Toronto. pp. 40-45.

Zwambag, E.P. 1985. Control of round leaf mallow in wheat. ECW report. p. 722.

APPENDIX 1

MUNICIPALITY OF PEMBINA

MUN. OF PEMBINA
 PROVINCE OF MANITOBA
 DEPARTMENT OF TRANSPORTATION



APPENDIX 2

CLIMATOLOGICAL DATA

WINNIPEG, MANITOBA

1985 AND 1986

Appendix Table 1. Maximum, minimum and mean temperatures, and precipitation for the growing season in Winnipeg, Manitoba (1985).

Date	May		June		July		August	
	Mean Temp. (C)	Precip. (mm)	Mean Temp. (C)	Precip. (mm)	Mean Temp. (C)	Precip. (mm)	Mean Temp. (C)	Precip. (mm)
1	-	-	6.8	0.6	17.5		20.0	
2	-	-	8.8		18.5		22.7	
3	-	-	11.2	6.8	22.5	0.2	21.7	24.1
4	-	-	7.6	2.4	20.0		20.2	8.4
5	-	-	12.2		22.1		21.3	0.2
6	-	-	19.9	1.0	24.3		21.1	
7	-	-	20.2		24.0		17.8	
8	-	-	17.2	3.2	20.4		21.2	4.2
9	-	-	13.3		18.6		13.8	0.2
10	-	-	10.6		17.8		12.9	
11	-	-	13.1		17.0		16.1	0.6
12	-	-	14.0		20.7	0.2	15.1	51.3
13	-	-	15.8		19.9	5.4	13.7	5.6
14	-	-	16.6	5.3	17.5	3.2	13.9	2.0
15	-	-	17.2		17.3		13.3	
16	-	-	14.8	2.0	20.5	17.8	12.9	20.4
17	-	-	11.4	8.7	17.9		11.1	77.0
18	-	-	14.6		19.3	2.0	10.6	
19	-	-	15.3		19.3	1.6	11.9	
20	-	-	18.9		15.6		13.2	
21	-	-	16.4	1.2	14.6		14.9	
22	-	-	9.7	0.8	17.1	1.4	19.1	
23	-	-	12.5		19.5	1.2	16.3	
24	-	-	12.3	2.6	14.7		17.8	
25	-	-	17.2	7.4	16.8		18.4	
26	-	-	13.9		16.6		18.9	
27	-	-	10.3	22.8	20.6	1.0	13.8	
28	-	-	13.1	2.4	15.3		12.4	
29	-	-	15.4		16.4		12.5	
30	-	-	18.3	0.2	19.4		16.9	0.8
31	11.3	7.5			19.6		19.1	

¹Environment Canada, Winnipeg International Airport

Appendix Table 2. Maximum, minimum and Mean temperatures, and precipitation for the growing season in Winnipeg, Manitoba (1986).

Date	May		June		July		August	
	Mean Temp. (C)	Precip. (mm)	Mean Temp. (C)	Precip. (mm)	Mean Temp. (C)	Precip. (mm)	Mean Temp. (C)	Precip. (mm)
1	-	-	13.4		19.2		17.3	5.3
2	-	-	18.9	2.6	16.7		16.3	
3	-	-	18.4		23.2	14.6	19.9	
4	-	-	11.9		20.1		21.5	
5	-	-	15.1		20.6	2.2	20.2	
6	-	-	20.5	8.1	17.1		22.2	3.8
7	-	-	15.0		18.5		19.6	1.2
8	-	-	12.3		18.6	0.2	20.1	
9	-	-	18.2	0.4	18.7		14.8	1.0
10	---	-	16.4		16.3	41.6	13.6	
11	-	-	16.7		18.2	4.4	16.2	
12	-	-	16.8	0.6	14.4	2.6	18.8	
13	-	-	15.1		17.0		21.0	
14	-	-	11.4	1.4	19.6	0.6	21.7	
15	-	-	12.4	5.6	20.6		22.4	
16	-	-	10.7		23.2		16.7	
17	-	-	16.5		22.5	5.6	13.7	
18	-	-	22.4		21.9		18.6	
19	-	-	23.9	9.5	18.4	1.7	24.8	
20	-	-	21.7	5.0	16.8	0.4	14.2	
21	-	-	21.9	8.3	19.2		15.0	
22	-	-	18.6		19.6		15.2	1.0
23	-	-	13.1		24.7	1.0	16.0	
24	16.7		15.3		19.4		18.6	4.1
25	19.8	1.2	22.1	1.2	19.4		14.4	
26	21.0	15.7	19.8	15.7	20.8	14.9	9.3	0.2
27	21.1		19.0		20.2		11.7	0.4
28	24.7		17.2		20.9	5.2	13.3	
29	25.8		13.7		21.8	20.8	17.7	
30	23.2	0.8	17.0	0.8	19.5	1.4	20.3	
31	19.6				18.1	0.8	17.0	

¹Environment Canada, Winnipeg International Airport

APPENDIX 3
CLIMATOLOGICAL DATA
MANITOU, MANITOBA
1985

Appendix Table 1. Maximum, minimum and mean temperatures, and precipitation for the growing season in Manitou, Manitoba (1985).

Date	May		June		July		August	
	Mean Temp. ¹ (C)	Precip. ² (mm)	Mean Temp. ¹ (C)	Precip. ² (mm)	Mean Temp. ¹ (C)	Precip. ² (mm)	Mean Temp. ¹ (C)	Precip. ² (mm)
1	-	-	6.5	-	17.8	-	19.5	-
2	-	-	7.8	-	18.8	0.8	20.5	-
3	-	-	11.3	3.0	22.8	1.2	20.5	45.6
4	-	-	8.3	-	20.0	-	19.8	9.6
5	-	-	13.3	1.2	22.3	-	21.8	-
6	-	-	20.0	-	24.8	-	20.8	-
7	-	-	21.5	25.0	25.0	-	19.0	-
8	-	-	19.3	-	20.8	-	20.5	-
9	-	-	15.5	0.8	20.0	0.8	14.3	-
10	-	-	11.3	-	18.3	-	12.3	-
11	-	-	12.5	-	17.8	-	14.0	7.4
12	-	-	13.3	-	21.0	-	14.5	8.6
13	-	-	17.3	-	21.5	4.4	14.8	6.6
14	-	-	15.8	12.2	17.5	0.8	14.8	-
15	-	-	17.8	12.4	18.3	-	14.5	-
16	-	-	15.3	4.4	22.8	14.4	13.5	61.0
17	-	-	12.0	2.8	18.8	-	12.3	5.0
18	-	-	15.5	-	19.5	4.0	11.3	-
19	-	-	15.5	-	19.5	11.8	12.3	-
20	-	-	20.5	-	16.3	-	12.5	-
21	-	-	16.5	27.6	16.5	-	13.3	-
22	-	-	11.3	-	17.5	-	18.5	7.4
23	-	-	12.5	-	22.8	-	14.8	0.8
24	-	-	13.0	19.2	15.8	-	18.0	-
25	-	-	16.0	17.6	16.5	1.0	18.0	-
26	-	-	14.0	3.8	17.5	-	21.0	0.2
27	-	-	11.0	16.4	19.5	-	15.3	-
28	-	-	12.0	3.2	15.5	-	11.5	2.0
29	-	-	13.3	0.4	16.5	-	13.8	-
30	-	-	17.3	-	18.8	-	15.5	1.8
31	12.8	2.0	-	-	19.8	-	21.0	-

¹From CDA Morden, Manitoba

²From Climatological Station Manitou/Strange, Manitoba

APPENDIX 4

CLIMATOLOGICAL DATA

PORTAGE LA PRAIRIE, MANITOBA

1986

Appendix Table 1. Maximum, minimum, and mean temperatures, and precipitation for the growing season in Portage la Prairie (1986).¹

Date	May		June		July		August	
	Mean Temp. (C)	Precip. (mm)	Mean Temp. (C)	Precip. (mm)	Mean Temp. (C)	Precip. (mm)	Mean Temp. (C)	Precip. (mm)
1	-	-	12.7		17.9		16.3	0.8
2	-	-	18.7	0.6	17.5		16.8	
3	-	-	18.1		23.8	20.2	20.5	2.0
4	-	-	11.5		20.5	0.2	20.6	
5	-	-	14.7		20.5	5.0	10.5	
6	-	-	19.4	13.9	17.3		21.2	6.0
7	-	-	16.3		18.6		20.2	
8	-	-	12.9		18.9	5.0	20.1	
9	-	-	16.9		18.1	13.8	15.4	2.4
10	-	-	15.1		15.6	39.0	13.5	
11	-	-	17.6		17.0	9.3	15.8	
12	-	-	15.3		14.5	1.6	20.6	
13	-	-	14.2	0.3	16.9	0.9	22.7	
14	-	-	11.3	1.8	20.4	1.4	21.2	
15	-	-	12.2	7.6	21.2		21.8	
16	-	-	11.8		21.6		17.5	
17	-	-	17.6		21.3	13.5	14.0	
18	-	-	21.6		21.4		18.1	
19	-	-	24.6	12.2	18.6	14.6	25.5	1.8
20	-	-	20.7	1.8	16.9		15.1	
21	-	-	21.3	15.6	20.0		15.7	
22	-	-	18.5	1.4	20.6		14.1	6.0
23	-	-	12.1	4.0	24.5	7.6	16.3	
24	-	-	16.2		19.3		19.3	
25	-	-	21.4	0.8	20.4	1.8	13.5	
26	-	-	18.3	32.6	21.0	1.8	10.2	
27	-	-	18.3		20.1		10.7	
28	-	-	17.6		21.3	2.0	14.8	
29	-	-	14.7		22.4	8.4	20.0	
30	-	-	16.0	0.2	19.3		20.3	
31	-	-			18.4	3.0	16.5	

¹From CFB Portage la Prairie, Manitoba

APPENDIX 5

DATA

POT GROWN MALLOW

1985 AND 1986

Appendix Table 1. Growth of mallow in pots (1985)

Weeks	No. true	Leaf area per plant (cm ²)	Dry Weight of Plant Parts			
			Stems and petioles (g)	Leaves (g)	Flowers (g)	Fruits (g)
1	1.8 + 0.1	1.1 + 0.2	0.00 + 0.00	0.002 + 0.0001		
2	3.3 + 0.4	3.3 + 1.2	0.01 + 0.001	0.02 + 0.005		
3	6.0 + 0.3	18.4 + 2.5	0.03 + 0.003	0.07 + 0.007		
4	14.1 + 0.8	80.6 + 11.1	0.15 + 0.03	0.33 + 0.05		
6	37.4 + 1.4	287.0 + 16.0	1.12 + 0.11	1.38 + 0.06	0.06 + 0.01	0.06 + 0.02
7	52.0 + 3.3	382.0 + 32.5	1.86 + 0.11	1.99 + 0.13	0.15 + 0.01	0.28 + 0.05
8	80.5 + 3.6	483.0 + 30.1	3.73 + 0.21	2.99 + 0.18	0.34 + 0.02	1.92 + 0.31
9	112.1 + 8.7	650.0 + 30.6	3.49 + 0.41	2.32 + 0.07	0.21 + 0.04	3.02 + 0.34
11	128.0 + 10.1	408.3 + 41.0	3.07 + 0.24	2.07 + 0.23	0.36 + 0.04	4.26 + 0.47
13	0.0 + 0.0	0.0 + 0.0	3.35 + 0.59	0.30 + 0.01	0.0 + 0.0	4.90 + 0.22

Appendix Table 2. Growth of mallow in pots (1986)

Weeks	No. true leaves	Leaf area per plant (cm ²)	Dry Weight of Plant Parts			
			Stems and petioles (g)	Leaves (g)	Flowers (g)	Fruits (g)
1	4.1 + 0.6	12.0 + 2.1	0.01 + 0.001	0.04 + 0.007		
2	10.0 + 1.2	79.0 + 4.4	0.01 + 0.03	0.32 + 0.22		
3	18.0 + 0.7	218.0 + 3.4	0.45 + 0.40	0.84 + 0.28	0.04 + 0.003	
4	26.3 + 3.1	410.0 + 14.0	1.26 + 0.21	2.04 + 0.30	0.14 + 0.09	0.31 + 0.02
5	72.0 + 3.1	888.0 + 20.3	4.02 + 0.30	5.15 + 2.11	0.56 + 0.12	0.56 + 0.04
6	104.0 + 6.2	1151.0 + 16.7	11.81 + 0.21	7.76 + 1.11	1.02 + 0.11	1.19 + 0.32
7	141.1 + 4.3	1266.0 + 23.3	18.77 + 0.41	8.88 + 3.00	0.69 + 0.04	6.61 + 0.03
8	147.7 + 5.2	659.0 + 22.4	18.20 + 0.59	7.36 + 2.65	0.10 + 0.06	11.98 + 1.10
9	167.2 + 9.1	487.0 + 30.1	13.04 + 0.24	4.71 + 1.75	0.16 + 0.03	17.45 + 2.30
10	118.8 + 1.3	91.0 + 2.1	15.39 + 2.42	4.31 + 1.70	0.08 + 0.01	16.96 + 1.55
13	46.5 + 6.2	49.0 + 0.8	9.21 + 1.00	0.38 + 0.09	0.05 + 0.002	15.42 + 2.00

APPENDIX 6

RAW FIELD DATA (MALLOW)

MANITOU, MANITOBA

1985

Appendix Table 1. Growth of mallow in a flax field at Manitou,
Manitoba (1985)

Weeks	Leaf area (cm ² m ⁻²)	Dry Weight of Plant Parts		
		Leaves	Stems and petioles	Fruits
		(gm ⁻²)	(gm ⁻²)	(gm ⁻²)
<u>Rep. 1.</u>				
1	408	0.7	0.2	
2	1188	1.7	0.5	
4	3666	13.2	11.9	11.1
5	5889	23.2	29.9	20.1
7	10847	42.0	100.0	38.5
8	8176	39.1	133.0	52.6
9	8227	32.2	161.2	60.3
13	0	0.0	130.0	78.7
<u>Rep. 2.</u>				
1	500	0.5	0.3	
2	1245	2.2	0.5	
4	4000	16.1	12.6	10.0
5	5601	23.7	32.9	24.3
7	9460	50.0	161.0	32.4
8	7234	32.4	153.8	63.2
9	9113	29.8	151.3	77.3
13	0	0.0	129.7	86.4
<u>Rep. 3.</u>				
1	316	0.9	0.1	
2	1018	0.9	0.6	
4	2989	12.3	9.7	13.5
5	5723	25.9	28.3	19.1
7	12334	38.6	82.3	31.2
8	9122	36.2	117.4	40.0
9	8838	30.2	123.5	52.3
13	4	0.01	102.4	64.1

Appendix Table 2. Growth of mallow¹ in a flax field at Manitou,
Manitoba (1985)

Weeks	Dry Weight of Plant Parts			
	Leaf area (cm ² m ⁻²)	Leaves (gm ⁻²)	Stems and petioles (gm ⁻²)	Fruits (gm ⁻²)
<u>Rep. 1.</u>				
1	483	0.6	1.8	
2	649	4.0	4.6	
4	1466	12.3	2.3	
5	1100	8.3	9.9	
7	1311	12.1	11.9	
8	4900	15.6	12.2	29.3
9	9249	40.7	29.9	20.6
13	8979	34.6	55.9	48.0
<u>Rep. 2.</u>				
1	471	0.6	2.2	
2	541	4.1	5.6	
4	1333	13.4	2.1	
5	1221	9.2	10.0	
7	1450	14.8	12.3	
8	5109	17.3	13.8	30.4
9	10032	42.9	38.9	31.7
13	9113	36.0	60.0	58.9
<u>Rep. 3.</u>				
1	500	0.6	2.8	
2	721	4.8	5.6	
4	1590	14.1	3.3	
5	1262	10.3	11.1	
7	1501	16.2	13.6	
8	6214	18.0	17.5	30.5
9	1200	44.4	45.2	44.7
13	1000	39.9	67.6	67.9

¹Sprayed with bromoxynil and MCPA

Appendix Table 3. Growth of mallow in a wheat field at Manitou,
Manitoba (1985)

Weeks	Leaf area ($\text{cm}^2 \text{ m}^{-2}$)	Dry Weight of Plant Parts		
		Leaves (gm^{-2})	Stems and petioles (gm^{-2})	Fruits (gm^{-2})
<u>Rep. 1.</u>				
1	4	0.01	0.0	
2	93	0.4	0.2	
4	1192	2.6	1.9	
5	487	2.2	2.3	1.0
7	545	5.0	8.7	3.0
8	699	7.2	10.8	5.0
9	317	7.8	11.0	9.0
13	2	0.3	0.8	9.5
<u>Rep. 2.</u>				
1	5	0.02	0.0	
2	80	0.3	0.1	
4	1226	3.4	2.2	
5	555	3.0	3.3	0.6
7	636	5.9	9.1	1.9
8	799	8.5	11.5	6.9
9	425	8.7	12.4	7.5
13	0	0.0	0.0	8.1
<u>Rep. 3.</u>				
1	2	0.01	0.0	
2	102	0.4	0.3	
4	1003	2.0	1.0	
5	500	2.1	2.2	2.3
7	648	6.2	7.4	2.1
8	533	6.8	9.3	8.3
9	301	6.8	10.2	9.2
13	1	0.01	0.3	10.0

Appendix Table 4. Growth of mallow in a wheat field¹ at Manitou,
Manitoba (1985)

Weeks	Leaf area (cm ² m ⁻²)	Dry Weight of Plant Parts		
		Leaves (gm ⁻²)	Stems and petioles (gm ⁻²)	Fruits (gm ⁻²)
<u>Rep. 1.</u>				
1	0	0.0	0.0	
2	410	2.1	1.3	
4	469	1.2	3.1	
5	699	3.0	7.2	
7	762	2.2	19.0	1.3
8	800	3.0	13.3	1.8
9	923	2.9	16.3	1.6
13	332	7.8	3.2	1.0
<u>Rep. 2.</u>				
1	0	0.0	0.0	
2	378	2.1	2.3	
4	404	3.4	6.2	
5	591	3.6	8.0	
7	700	3.6	19.3	1.2
8	797	4.5	19.7	1.8
9	900	4.9	17.8	1.6
13	300	8.2	3.9	0.9
<u>Rep. 3.</u>				
1	5	0.01	0.002	
2	444	4.0	3.5	
4	500	6.0	9.3	
5	777	3.8	9.4	
7	881	4.1	19.7	1.0
8	840	5.2	27.5	1.7
9	944	5.2	18.0	1.5
13	349	9.1	4.2	0.8

¹Sprayed with bromoxynil and MCPA

APPENDIX 7

RAW FIELD DATA (MALLOW)

PORTAGE LA PRAIRIE

1986

Appendix Table 1. Growth of mallow in a flax trial at Portage la Prairie Research Station, Manitoba (1986)

Weeks	Leaf area ($\text{cm}^2 \text{m}^{-2}$)	Dry Weight of Plant Parts		
		Leaves (gm^{-2})	Stems and petioles (gm^{-2})	Fruits (gm^{-2})
<u>Rep. 1.</u>				
1	0	0.0	0.0	
3	487	3.2	1.8	
4	500	3.5	1.8	
5	400	1.9	1.6	
6	300	0.9	1.1	
7	204	0.6	0.8	2.3
8	163	0.5	0.6	4.7
11	48	0.4	0.5	3.0
<u>Rep. 2.</u>				
1	0	0.0	0.0	
3	501	4.9	1.8	
4	550	3.2	1.7	
5	439	1.0	1.4	
6	287	0.3	1.0	
7	196	0.8	1.1	1.3
8	171	0.3	0.4	5.6
11	52	0.2	0.3	4.0
<u>Rep. 3.</u>				
1	0	0.0	0.0	
3	466	2.4	1.7	
4	449	3.6	1.7	
5	460	2.2	1.6	
6	333	1.1	1.1	
7	212	0.7	0.8	2.9
8	150	0.6	0.5	3.1
11	37	0.4	0.4	2.0

Appendix Table 2. Growth of mallow in a flax trial¹ at Portage la Prairie Research Station, Manitoba (1986)

Weeks	Leaf area (cm ² m ⁻²)	Dry Weight of Plant Parts		
		Leaves (gm ⁻²)	Stems and petioles (gm ⁻²)	Fruits (gm ⁻²)
<u>Rep. 1.</u>				
1	0	0.0	0.0	
3	204	1.7	1.8	
4	333	1.2	2.1	
5	191	0.9	1.9	
6	143	0.8	1.5	2.1
7	111	0.8	1.5	4.5
8	69	0.7	1.1	4.2
11	70	0.7	1.1	4.0
<u>Rep. 2.</u>				
1	0	0.0	0.0	
3	171	1.5	1.9	
4	498	2.4	2.2	
5	542	3.6	1.9	
6	306	1.2	1.9	3.6
7	149	0.8	1.0	4.9
8	99	0.7	1.2	5.8
11	82	0.7	1.2	5.3
<u>Rep. 3.</u>				
1	0	0.0	0.0	
3	212	1.6	2.1	
4	269	1.6	2.3	
5	100	0.7	2.0	
6	98	0.7	1.7	2.5
7	76	0.7	1.2	3.6
8	80	0.7	1.1	3.8
11	65	0.6	1.1	3.9

¹Sprayed with bromoxynil and MCPA

Appendix Table 3. Growth of mallow in a wheat trial at Portage la Prairie Research Station, Manitoba (1986)

Weeks	Leaf area (cm ² m ⁻²)	Dry Weight of Plant Parts		
		Leaves (gm ⁻²)	Stems and petioles (gm ⁻²)	Fruits (gm ⁻²)
<u>Rep. 1.</u>				
1	0	0.0	0.0	
3	49	0.9	0.9	
4	101	0.8	0.4	
5	98	0.8	0.3	
6	73	0.8	0.3	
7	44	0.8	0.3	2.2
8	32	0.9	0.4	3.1
11	31	0.9	0.4	3.1
<u>Rep. 2.</u>				
1	0	0.0	0.0	
3	53	1.0	1.1	
4	112	0.9	0.6	
5	99	0.9	0.5	
6	88	0.9	0.5	
7	40	0.7	0.5	2.1
8	22	0.8	0.5	2.9
11	10	0.5	0.3	3.1
<u>Rep. 3.</u>				
1	0	0.0	0.0	
3	39	0.8	0.9	
4	96	0.8	0.3	
5	98	0.8	0.3	
6	62	0.8	0.3	
7	56	0.7	0.3	1.9
8	53	0.7	0.3	3.2
11	44	0.7	0.3	3.0

Appendix Table 4. Growth of mallow in a wheat trial¹ at Portage la Prairie Research Station, Manitoba (1986)

Weeks	Leaf area (cm ² m ⁻²)	Dry Weight of Plant Parts		
		Leaves (gm ⁻²)	Stems and petioles (gm ⁻²)	Fruits (gm ⁻²)
<u>Rep. 1.</u>				
1	0	0.0	0.0	
3	106	1.8	1.2	
4	90	1.8	1.2	
5	87	1.8	2.0	
6	84	1.5	2.3	1.7
7	79	1.3	1.8	2.1
8	62	1.1	1.6	2.9
11	51	1.1	1.6	3.1
<u>Rep. 2.</u>				
1	0	0.0	0.0	
3	115	1.9	1.1	
4	88	1.9	1.2	
5	73	1.7	1.9	
6	86	1.7	2.2	
7	66	1.6	1.9	1.8
8	80	1.3	1.7	2.0
11	62	1.3	1.7	3.2
<u>Rep. 3.</u>				
1	0	0.0	0.0	
3	103	1.6	1.3	
4	99	1.6	1.3	
5	92	1.6	2.2	
6	70	1.6	2.5	1.6
7	86	1.3	1.8	2.2
8	75	1.0	1.5	3.2
11	40	1.0	1.5	3.3

¹Sprayed with bromoxynil and MCPA