# EVALUATION OF OILSEED BRASSICAS FOR RESISTANCE TO THE TURNIP APHID, LIPAPHIS ERYSIMI (KALT.)

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# CHAPTER I

# INTRODUCTION

Oilseed cruciferous crops include the plant species Brassica campestris L., Brassica carinata Braun, Brassica juncea (L.) Coss., Brassica napus L., Brassica hirta Moench, Brassica nigra (L.) Koch, and Eruca sativa Lam. The vernacular name used for these crops are rapeseed and mustard. Rapeseed and mustard are grown all over the world. Total area planted with these crops was 13,120,000 ha in 1982. The major area distribution was 4,384,000 ha in China, 4,337,000 ha in India, 1,717,000 ha in Canada, 475,000 ha in France, and 238,000 ha in Pakistan (Anonymous 1983). In Pakistan, the major areas where rapeseed and mustard are grown are in the Punjab and Sind Provinces. The crops are planted in October and harvested in May.

Rapeseed and mustard rank fifth among world oil crops in tonnage production. Average yield varies in different countries, and it depends upon climate and production technology. In European countries, the average is 2.00 ton/ha, whereas in Pakistan it is only 0.57 ton/ha (Khan et al. 1987). There are many factors responsible for low yield in the India-Pakistan subcontinent, but insect damage, especially by aphids is a major problem. In India, Prasad & Phadke (1984) found that the average yield loss for three years (1981-84) was 48.3% for rai, a variety of B. juncea, and 64.7% for brown sarson, a variety of B. campestris, and 77.8% for yellow sarson, a variety of B. campestris. In Pakistan, actual losses due to aphid damage have not been reported in the scientific literature, but aphid damage is generally considered to be the major constraint in rapeseed and mustard production, especially in the Sind Province where aphid infestations may totally destroy the crop.

The different aphid species attacking the rapeseed and mustard crops in India and Pakistan include the turnip aphid, Lipaphis erysimi (Kaltenbach); the cabbage aphid, Brevicoryne brassicae L., and the green peach aphid, Myzus persicae (Sulzer) (Ullah 1940). Intensive work has been done on L. erysimi, which is the most serious pest of the crop.

Several measures can be used to control aphid populations on rapeseed and mustard, but resistant cultivars are ideal because they are safe, cost effective, easily implemented and compatible with other methods. This is especially true in Pakistan where farmers have small holdings on which they grow the crop for their own use. Also, rapeseed and mustard are grown on marginal land, because wheat is the preferred crop on the good land. Due to high prices for pesticides and low yields, it is not economical to apply pesticides for aphid control on rapeseed and mustard. In Pakistan, some efforts have been made to evaluate rapeseed and mustard varieties for aphid resistance; e.g. Chatta (1982) and Beg (1986), but no promising sources of resistance have been found. However, Hussain (1983) studied rates of population increase for cabbage aphid on different varieties of oilseed brassicas and found that the population growth was significantly slower on B. carinata, in comparison to other species.

There is a great need to conduct host plant resistance studies on rapeseed and mustard for aphid resistance in Pakistan. In this manuscript, I am reporting host plant resistance studies on rapeseed and mustard against turnip aphids in the laboratory as well as in the field at the National Agricultural Research Center, Islamabad, Pakistan, during 1988-1989, and some research at Oklahoma State University, Stillwater, U.S.A. during 1989-1990.

# CHAPTER II

# LITERATURE REVIEW

## Aphid Pests of Brassica Crops

B. brassicae, L. erysimi and M. persicae are the serious pests of brassica crops like cabbage, cauliflower, broccoli, collard, kale, rapeseed and mustard. These aphids cause heavy damage to rapeseed and mustard in different countries such as B. brassicae in New Zealand, and L. erysimi in India. In Pakistan, aphids also cause serious damage to rapeseed and mustard, and during some years may result in the total failure of the crop in the southern region (Sind Province). To minimize yield loss by these aphid pests of oilseed brassica, resistant cultivars constitute an ideal method of control.

## Cabbage Aphid Biology

The cabbage aphid, B. brassicae, is dimorphic (winged or wingless), parthenogenetic, and ovoviviparous. Theobald (1927) said that in Britain B. brassicae appeared in May and formed colonies on the crucifer leaves. By June alatae appeared and migration began. In November, alate males and oviparous females mated and the eggs were laid on winter greens. In March, stem mothers hatched from eggs and started reproducing parthenogenetically. There are some variations in the life cycle in different years due to seasonal variations as reported by Hughes (1963) in Australia, and Raworth (1984a) in Canada. Hughes (1963) reported four instars and a physiological threshold temperature of 41°F (4.5°C). Each of the four instars took an average of 56 DD., and adult longevity averaged 268 DD. Hughes & Gilbert (1968) developed a computer model based on day-degree requirements to estimate population increase in the field. The input parameters were rates of reproduction of apterae and alatae, developmental time, emigration, alate formation, crowding loss, loss by predation and parasitism, and hyperparasitism.

B. brassicae is an oligophagous aphid feeding on cruciferous plants like cabbage, kale, brussels sprouts, cauliflower, rapeseed and mustard. Bonnemaison (1965), in a review paper about the insect pests of crucifer and their control, mentioned B. brassicae as a major pest of crucifers in many countries. Lamb (1989) reported that B. brassicae is a major pest of oilseed brassica in New Zealand and Australia, but in India, L. erysimi is the major pest on the oilseed brassica.

Regarding host plant selection Kennedy et al. (1961) reported that B. brassicae and M. persicae in the field preferentially alight on leaves that reflect a greater proportion of long wave length >500 mμ energy. Botanical (plant taxonomic) status of plant was found to play only a small role. They also found twice as many B. brassicae alatae on sugarbeet leaf discs than on cabbage leaves. Also, Kennedy et al. (1959) found the host preference exhibited by B. brassicae and M. persicae was influenced more by color of leaves than by their nutrient value. In their study, alatae of B. brassicae preferred cabbage plants with green leaves over red leaves, but as the season progressed, red leaves became more acceptable to both B. brassicae and M. persicae. After landing on the leaves, sinigrin seems to play an important role as a strong phagostimulant for B. brassicae to feed on crucifers.

Raworth et al. (1984a) studied population dynamics of B. brassicae on kale in British Columbia, Canada and developed a volumetric technique for assessing aphid numbers. They sampled three leaves from upper, middle, and lower portions of kale plants. The fields were sampled at 7 to 14 day intervals from the last week of June to the first week of October. Sampling showed that population growth rate declined after the appearance of Diaeretiella rapae (M'Intosh), a hymenopterous parasite and Aphidolatus aphidmiyza (Rondani), a predatory larva in the Syrphidae. Other factors responsible for decline were leaf senescence, reduced proportions of oviparous females, increased alate production, and comparatively low temperature at the end of August.

Raworth et al. (1984b) reported the developmental threshold temperature as (6.7℃), and developmental time from birth to adult was 126℃ DD. Developmental times for 1st, 2nd, 3rd, and 4th instar apterous nymphs were 31.7, 32.9, 27.8, and 33.9℃ DD, respectively. Fecundity rate was 40.7 nymphs per female in laboratory studies. In the field, developmental time was 1.3 times longer, fecundity was 0.34 less, and longevity 1.2 times longer than in laboratory studies. Raworth et al. (1984b) studied the effect of aphid numbers and water stress on B. brassicae in field. Water stress had no significant effect on fecundity, adult weight, aphid number and age distribution, but different aphid density treatments such as low, medium, and high, significantly affected the final aphid number per plant, number per unit of leaf area, and adult weight at the end of the experiment.

Raworth (1984b) studied the predation of cabbage aphid by A. aphidimyza and found that the predator consumed 1.7 times more aphids in the laboratory than in the field during larval development. However, total weight of prey was the same in both cases, i. e. 2.14 mg because field weight per aphid was more than the laboratory weight. Raworth (1984c) developed a computer model on the basis of all the above information to simulate the population dynamics of cabbage aphid.

According to Raworth (1984a) laboratory and field measurements of developmental time, fecundity and longevity differed due to plant quality. Certain fertilizer treatments which enhanced total soluble nitrogen concentration also increased reproductive performance of B. brassicae and M. persicae on brussels sprouts. Total soluble nitrogen concentration in plants provides a useful indicator of susceptibility to aphids, but it may vary with plant age, as van Emden and Bashford (1971) showed that plant age significantly affected the total soluble nitrogen concentration in leaves. The concentration of different amino acids varied with plant age; it was generally lowest in the younger plants and reached a peak in 6 to 9-week old plants and then declined. Asparagine, glutamine (amide) and glutamic acid declined with increasing plant age, but proline increased with plant age.

van Emden and Bashford (1971) also observed the relative growth rate (RGR) based on weight increment per day per initial weight of the aphid for B. brassicae and M. persicae reared on brussels sprouts for 3-4 days at different plant ages. RGR for B. brassicae and M. persicae decreased significantly as plants grew from 6 to 15-weeks. Maximum RGR for B. brassicae occurred on

6-week old plants, whereas RGR on 3-week old plants was normally 50% less. Wearing (1967a,b) studied the effect of water stress in host plants on aphid infestation and concluded that the reproductive rate of *B. brassicae* decreased with increasing water stress. In subsequent work he reported that decreased reproduction with water stressed plants occurred only in mature leaves, while at the plant terminal reproduction actually increased. Wearing (1972a,b) used 'Jude Cross' brussels sprouts to determine preference of apterous and alate *B. brassicae* and *M. persicae* for different aged leaves of the host plants, i. e. young, mature, and senescent, under three different water stress conditions based on available water deficiency, i.e. wet (10%), medium (50%), and dry (90%). Alate *B. brassicae* preferred medium water stressed plants (33.1 aphids/plant) in comparison to wet (26.1 aphids), or dry plants (17.1 aphids). In the water regime, alatae preferentially settled on mature leaves followed by young leaves. The rate of reproduction of *B. brassicae* was highest (3.39/day) on young leaves of the dry regime while that of *M. persicae* was highest (3.87/day) on old leaves of the medium regime. Miles et al. (1982) reported the rate of development of *B. brassicae* on *B. napus* was significantly increased on water stressed plants as compared to wet plants. The availability of free amino acid, especially proline, was significantly higher on water stressed plants. There was no significant difference in fecundity on stressed and unstressed plants.

Carlson (1973) evaluated several insecticides for control of cabbage aphid and turnip aphid on rapeseed and mustard plant; principally after cabbage aphids were present in large numbers and the turnip aphid comprised at least 10% of aphid population. The economic threshold, determined by selecting plants with a different number of aphids was 100 to 200 aphids per 12.7 cm of terminal or ca. 0.083 aphids per millimeter of stem and pod. Severity of the damage to plants increased significantly with 200 to 250 or more aphids per terminal. He indicated that the turnip aphid is less damaging than the cabbage aphid in California.

## Turnip Aphid Biology

L. erysimi, referred to as both the mustard aphid and turnip aphid (Blackman and Eastop 1984), is a serious pest on oilseed brassica in India. It is common from November to March on the rapeseed and mustard crops. Ghosh (1980) reported that L. erysimi infestations started at the early seedling stage on rapeseed and mustard with the arrival of alate, viviparous females during mid-November in West Bengal, India. The turnip aphid is a well-known and serious pest of cabbage, broccoli, radish, and other crucifers (Jarvis 1970).

Nault and Styer (1972) investigated response of six aphid species to sinigrin, a mustard oil glucoside, and found that it is a powerful phagostimulant for L. erysimi and B. brassicae. Its effect was dramatic as L. erysimi settled, fed, and reproduced on 10 non-host species systemically treated with sinigrin. Rout and Senapati (1968) studied the biology of the turnip aphid on radish plants in the laboratory, and reported that the average age duration intervals for apterous and alate aphids were: 7.5 and 9.5 days for prereproductive; 9.7 and 8.4 days for reproductive; 1.3 and 1.0 days post-reproductive; and 18.5 and 18.9 days total longevity when reared at an average temperature of 25.5°C. The average nymphal production by apterae and alatae was 42.6 and 35.5, respectively.

Phadke (1982) reported the net reproductive rate (Ro) and intrinsic rate of increase for L. erysimi under field conditions on four brassica varieties: yellow sarson, 'Ys-Pb-24' (114.4, 0.206); brown sarson, 'BSH-1' (94.2, 0.155); toria, 'T-9' (119.4, 0.206); and rai, 'Pusa Bold' (86.1, 0.165). He selected four leaves of the same age and size and observed individual aphids from birth to death. He suggested that the cultivars Ys-Pb-24 and T-9 are the most favorable for aphid reproduction. Landin & Wennergren (1987) said that rate of increase of L. erysimi was highest at 25℃, and the aphids died at 35℃ without reproducing. Ram & Gupta (1988) reported that the numbers of turnip aphids decreased with increased levels of phosphorus and potassium in plants whereas populations increased with a high level of nitrogen fertilization.

Prasad & Phadke (1980) studied the population dynamics of L. erysimi on different mustard cultivars. Despite differences in flowering and maturity dates, the date of peak aphid population was the same (February 10). The numbers started to decline when the flowering phase was over. Bakhetia & Sidhu (1983) reported the effect of rainfall on turnip aphid numbers on 'RLM- 198' (B. juncea) during 1977. The aphid population count was highest (122/5cm inflorescence) on the second week of February, and declined to 27 aphid/5 cm inflorescence per plant due to 33 mm rainfall within the week.

Prasad & Phadke (1983) exposed a mustard cultivar, 'Pusa Kaly', to natural infestations of turnip aphid for different time periods after planting. There was a significant yield reduction when the exposure period was from 65-75 days after sowing. Prasad & Phadke (1984) planted cultivars of three different oilseed brassica varieties such as rai (B. juncea), brown sarson and yellow sarson (B. campestris). They weighed aphids collected from 20 cm lengths of inflorescence to estimate the numbers per plot. Over 3 years, the aphid numbers per shoot ranged from 344 to 379 on rai, 427 to 629 on brown sarson, and 361 to 676 on yellow sarson cultivars. Rai cultivars with low aphid numbers gave higher yields than the other cultivars.

Narrang & Atwal (1986) found that higher concentrations of the glucosinolate extracts from B. campestris, B. juncea, and E. sativa reduced turnip aphid survival, development, reproductive period, and fecundity. The different concentration of glucosinolate extracts from E. sativa at 2%, B. juncea at 3%, and B. campestris 4% were similar in their efficacy.

Singh et al. (1983a) reported a 45% seed yield reduction during 1978 due to turnip aphid attack. Singh et al. (1983b) concluded from their 3-year field study that economic injury level was 75 turnip aphids/10 cm terminal/plant, and their estimated benefit-cost ratio was maximum when the aphid population was 50 aphids/10 cm terminal/plant. They reported that each increase of one aphid beyond 25/plant decreased the yield at the rate of 1.5 kg/ha. Singh et al. (1984) reported that there was no significant yield reduction if B. juncea was infested at the pod formation stage, but infestation before that stage caused significant yield reductions. A 1-day delay in initiation of aphid infestation after 50 days beyond sowing (vegetative stage) resulted in an increase of 0.046 gm seed yield per plant, 2.2 pods per plant, 0.051 seeds/pod, and 0.003 gm/100 seed weight. At flowering stage (81 days after sowing), a 1-day delay in aphid infestation resulted in an increase of 0.046 gm in seed yield per plant, and 0.0008 gm per 100 seed weight.

Singh et al. (1985) described the relationship between percentage of flowers infested and number of aphids per plant, and reported that the two parameters were positively correlated, but the relationship was inconsistent in different years. The relationship was not evident at low (<22 aphids per plant) and high (>135 aphids per plant) populations.

## Host Plant Resistance

Painter (1951) suggested that the search for sources of resistance should be carried out in a logical sequence; first in adapted cultivars, then in plant introductions and exotic germplasm, and finally in near relatives of the crop species. In India, Singh and Bakhetia (1987) reviewed a variety of techniques and criteria for aphid resistance such as seedling survival, aphid injury, increase in aphid numbers during a given period, fecundity, longevity of the aphids and crop yield potential. Lamb (1960) and Lammerink (1968) also used different rating schemes based on injury symptoms by cabbage aphid to brassica plants. Singh and Bakhetia (1987) summarized the host plant resistance work done by several authors on rapeseed and mustard crop against L. erysimi in India. According to their results 'RL-18', 'RLM-198', 'RLM-528', 'PR-15', 'PR-52' Rai-T3, Laha-101, (B. juncea); 'GGl-1', 'Karat', 'Gulliver', PI 171538 (B. napus); and ACC-751516 (B. hirta) were resistant and ; ITSA (Eruca sativa) were highly resistant; whereas 'Pusa Kalyani' (B. campestris); B-85, RK-2, RK-9, and Rh-785 (B. juncea) were tolerant.

In New Zealand a variety called 'Aphis Resistant Rape' having resistance to B. brassicae, but not to M. persicae or L. erysimi, was released. This cultivar had only 12 aphids per plant as compared to 1200 aphids per plant on the susceptible cultivar 'Broad Leaf Essex'. This cultivar was resistant only during the vegetative stage, but had no resistance during the flowering stage (Palmer 1960). Margretts (1963) conducted a yield trial for 3 years and reported that Aphis Resistant Rape was not immune but it was resistant to cabbage aphid as compared to other cultivars in New Zealand. In England, Dunn & Kempton (1969) studied the mechanism of resistance in Aphis Resistant Rape and reported that it was a combination of non-preference and antibiosis. Aphis Resistant Rape was only half as attractive to alate cabbage aphid as susceptible rape, and nymphs took about 13% longer to mature. Antibiosis also shortened the reproductive life of apterae by one third, reduced the fecundity by nearly 50%, and caused 40% mortality in the progeny.

Lamb (1960) studied the susceptibility of eight brassica cultivars under field conditions in New Zealand against B. brassicae and M. persicae. He found that 'Broad Leaf Essex' rape and 'Superlative' swede were highly susceptible to cabbage aphid; 'Wye' swede and 'Chou Moellier' marrow stem kale were moderately susceptible; while 'Doon Spartan' and 'Calder' swedes were resistant; and 'York Globe' and 'Green Globe' turnips were highly resistant.

Lamb and Lowe (1967) tested five cultivars at three locations in New Zealand. The susceptible cultivars were Superlative swede and Broad Leaf Essex rape, and Calder swede plus two lines of rape (825 and 827) were the resistant entries. According to their results, the three resistant cultivars had fewer aphid colonies than the two susceptible cultivars at all sites, and there were significant differences between sites for plant survival against combined aphid-virus attack. Different patterns in plant growth also had an effect on the pattern of growth in the aphid population.

Dodd and van Emden (1979) tested seven cultivars of brussels sprouts for B. brassicae resistance and selected two cultivars, 'Early Half Tall' (resistant) and 'Winter Harvest' (susceptible). There was a shift in resistance with plant stage. Potential increase rate (PIR) of B. brassicae was significantly higher on Winter Harvest (2.29) than Early Half Tall (1.59) when the plants were 67 days old, but there was no difference in PIR when the two cultivars were 129 days old.

Jarvis (1982) evaluated Brassicaceae oilseed plants for resistance to cabbage aphid in the greenhouse. All accessions of B. napus, B. carinata, and B. campestris var. Dicotoma were highly susceptible; and only two accessions of Crambe juncea Coss, i.e. PI 314075 and PI 325274, were highly resistant and may not be hosts of the cabbage aphid. Jarvis (1969) reported that mostly turnip aphids and some green peach aphids were present on crambe grown at Ames, Iowa, during the summer of 1967, and caused damage by stunting, wilting, leaf yellowing, and death of susceptible plants. He infested plants in a greenhouse with turnip aphids and counted surviving plants for each entry after 28 days. Only PI 247310 showed a high level of resistance to turnip aphid. This entry did not exhibit resistance to green peach aphid. Jarvis (1970) screened 390 oilseed crucifer entries for resistance against turnip aphid (then known as Hydaphis pseudobrassicae). PI 171538, an introduction of B. napus, was the only accession that showed resistance. Accessions of E. sativa were tolerant to turnip aphid damage and supported large populations with less damage than the checks.

In Pakistan, Hussain (1983) evaluated the standard entries of B. napus, B. campestris, B. juncea, B. nigra, B. trilocularis, and B. carinata for cabbage aphid resistance and concluded that B. carinata and B. trilocularis were resistant (antibiosis) and B. juncea was tolerant. Hashmi et al. (1985) studied the relative development of B. brassicae, Aphis medicaginis Koch and Aphis nerii Boyer de Jonscolambe (oleander aphid) on several entries of B. campestris, B. napus and B. juncea. On the basis of relative population development of the three aphid species, B. campestris was rated as susceptible, B. napus moderately resistant, and B. juncea was highly resistant.

Beg (1986) reported the evaluation of 560 entries of oilseed brassicas of different species for resistance to aphids at three locations in Pakistan: National Agricultural Research Center, Islamabad; Agricultural Research Station, D. I. Khan; and Agricultural Research Station, Tandojam, Hydarabad. Twenty-five entries of different species namely 955-5, 672-1, 'Daccca-Raya', 2396-8, K-408, B. juncea; 77-95, 3161-3, 'Ganyou-5', 77-20, 'Westar', B. napus; 77-1299, 1309-2, 77-1316, B. carinata; K-953, K-963, 879-1, K-905, K-1071, B. campestris; and Eruca sativa K-427, K-841, K-940, K-967, K-706 were tolerant, but in my tests of these entries only the E. sativa entries showed even moderate resistance.

After the evaluation of germplasm and finding of resistant sources, the next step is to identify the factor(s) causing the resistance. Thompson (1963) observed B. oleracea L. var. acephala plants segregating for waxy and non-waxy leaves; non-waxy leaves were not colonized by the cabbage aphid, whereas waxy plants had large colonies. Way & Murdie (1965) reported that brussels sprouts with waxy leaves generally supported larger populations of cabbage aphid than those with glossy leaves, but M. persicae preferred glossy leaves. Nault & Styer (1972) investigated the response of six aphid species to sinigrin (a mustard oil glucoside) and found that it was a powerful phagostimulant for L. erysimi and B. brassicae.

Wensler (1962) also reported that sinigrin was a specific stimulus in host selection by B. brassicae and was received through the stylets after they penetrated the leaf surface. He treated Vicia faba L. (a non-host) with sinigrin and after 24 h an average of 93% of the aphids were settled and feeding. Also, the presence of sinigrin increased the average number of probes per aphid by 1.3 times and duration of probes increased by 2.4 times.

# CHAPTER III

# SCREENING OF OILSEED BRASSICA GERMPLASM FOR APHID RESISTANCE

## Introduction

The turnip aphid, L. erysimi, is a serious pest of oilseed brassica, cabbage, broccoli, turnip, radish, and other crucifers. It is especially destructive to seedlings (Jarvis 1970). This insect attacks all plant growth stages from seedling to maturity and all plant parts expect the roots. The damaged leaves become curled, wrinkled, and yellowish; flower buds become distorted and fail to set pods; pods become twisted and shriveled, and the plant as a whole becomes stunted. Singh & Bakhetia (1987) reported in a review article that Sirohi et al. (1966) found a significant reduction in the mean number of primary, secondary, and tertiary branches in infested plants. Also, the turnip aphid damage reduced the number of pods, seed number, and seed weight between infested and uninfested plants of two mustard varieties.

Jarvis (1969, 1970, 1982) conducted greenhouse evaluation of cruciferous germplasm against B. brassicae, L. erysimi, and M. persicae at the seedling stage by comparing the percentage survival of seedlings after 21 to 28 days of infestation. Singh & Bakhetia (1987), in summarizing previous work on oilseed brassica screening methods, reported that Bakhetia (1975) and Bakhetia & Bindra (1977) also evaluated rapeseed and mustard germplasm for resistance to L.

erysimi at the seedling stage by counting the seedling survival. Many other authors screened the germplasm on the basis of aphid injury at different plant growth stages such as seedling, vegetative, budding, and flowering stages. Bakahatia and Bindra (1977) tested sixteen different cruciferous cultivars at different plant stages (two leaf, four leaf, and flowering) for resistance to the turnip aphid and categorized them in four different levels of resistance. The different cultivars were in the same category of resistance when evaluated at the different growth stages.

The oilseed program at the National Agricultural Research Center (NARC), Islamabad, Pakistan was seeking dependable sources of aphid resistance. The objective of this study was to determine possible sources of resistance in oilseed brassica against turnip aphid. It was concluded that brassica germplasm could be screened for resistance at the seedling stage using a controlled infestation level. Obviously, screening at the seedling stage has the advantage of handling a large number of entries for initial screening, and the controlled infestation levels should minimize the chances of plants escaping infestation. In these tests, I screened 230 entries of oilseed brassica germplasm at the seedling stage for resistance against L. erysimi in a laboratory at NARC.

## Materials and Methods

The turnip aphid, L. erysimi, was collected in 1988 from a rapeseed and mustard field at the NARC, Islamabad, Pakistan. The aphid population was propagated from a single aphid. The aphid population was maintained in isolation in a rearing room on 'Toria-A' (B. campestris) plants at 22° to 25°C.

A total of 230 entries of oilseed brassicas of B. campestris, B. carinata, B. juncea, B. napus, and E. sativa entries were obtained mostly from the oilseed program at the NARC; a few from Ayub Agricultural Research Institute, Faisalabad; two from University of Agriculture, Peshawar; and six from Sweden. These entries were screened in 14 different tests. In this preliminary screening of 230 entries of B. campestris (5), B. carinata (5), B. juncea (194), B. napus (16), B. hirta (4), and E. sativa (6) were tested for turnip aphid resistance. The majority of the entries were B. juncea which is a native oilseed brassica species of the Indo-Pakistan region. These 14 tests were not evaluated at the same time due to limited space. The planting dates for the different tests were: Test one - Oct 22, 1988; Test two - Oct. 29, 1988; Tests 3 through 6 - Nov. 8, 1988; Tests 7 through 11 - Dec. 8, 1988, and Tests 12 through 14 - Jan. 20, 1989.

Twenty entries were planted in each 75x45x10 cm metal tray filled with sandy soil, including two standard entries. The standard entries were Toria-A as susceptible and K-841 (E. sativa) as resistant. Twenty seeds of each entry were planted in each 20-cm long row. The plants were thinned to 10 plants per entry after seedling emergence and each entry was replicated twice at the same planting under randomized complete block design. The trays were put on 90 cm high tables in the laboratory where fluorescent lights provided a 16-h photophase at a temperature of 22° to 25°C. When the plants were at the two-leaf stage, they were artificially infested with aphids from the culture, at the rate of approximately 10 aphids/plant scattered between the rows with a camel's-hair brush. The trays were not caged. After one week of infestation, each plant was observed for aphid injury and the damage rated according to the following progressive rating scheme from 1-6:

1. No damage = Highly Resistant
2. Localized chlorosis on leaves = Resistant
3. Leaf margins curled = Moderately Resistant
4. Rolling of leaves = Moderately Susceptible
5. Yellowing and necrosis of leaves = Susceptible
6. Plants dead = Highly Susceptible

Some entries might tolerate aphid damage as well as have better plant growth as compared to other entries as the resistance might be based on tolerance (Smith, 1989). The number of leaves were counted to identify entries with this type resistance. The plant damage ratings and number of leaves were recorded for 3 weeks at 1-week intervals.

The data for damage rating and number of leaves for each week were analyzed using SAS (SAS Institute 1985) for each test independently by general linear model (GLM). The SAS GLM program model was: damage = entry, replications. The mean comparison was done by Duncan's Multiple Range Tests (DMRT) protected by F value at probability $P \leq 0.05$ (SAS Institute 1985) because there were no preplanned mean comparisons and each mean was considered to be independent.

Cluster analysis was done for each set considering all six variables of each entry (3 weekly leaf counts and 3 weekly damage ratings) to determine the maximum likelihood among entries in each set for resistance against turnip aphid at seedling stage. Each entry was represented by a vector in a six-dimensional space, the coordinates of which were defined by each entry's performance in each of six variables. The entries with similar responses in damage as well as in growth were clustered based on their proximity in six dimensional space. A cluster hierarchy was produced for each set of entries in a test using CLUSTER and TREE Procedures of SAS (SAS Institute 1985). The cluster hierarchy was truncated at the level corresponding to the initial sharp decline in $R^2$ (Carver et al. 1987).

## Results

TEST-1 (Table I): The first week damage rating data analyses showed that the entries were significantly different at $P = 0.0001$. Mean comparison of the entries by Duncan's Multiple Range Test (DMRT) (SAS Institute 1985) showed that there were five overlapping groups of the entries. Toria-A was damaged significantly more than all other entries. Only 'Mustard sag' and 'NARC-82' were damaged significantly more than K-841 (1.95). The second week damage rating analysis showed that the entries were different at $P = 0.002$. The mean comparisons among entries show that Mustard sag and 88028 were as damaged as Toria-A, and that NARC-82, BM-1, 'Candle' and 'PR-7' were intermediate in damage. Other entries were not significantly different from K-841. By the third week damage rating, the entries were significantly different at $P = 0.0003$. Mean comparison indicated Candle, Tatyoon, NARC-82, Mustard sag, PR-7, and 88028 were not significantly different from Toria-A and rated as susceptible. The entries K-658, UCD-6/7, 2396-8, K-940, K-90, and K-1027 were not significantly different from K-841 and were rated moderately resistant.

The relative growth of the entries was not significantly different until after the second week of infestation ($P = 0.002$). There were two major groups of entries, one which was not significantly different from Toria-A including Tatyoon, K-1027, K-940, NARC-82, PR-7, K-841 and K-658 and a second which had more growth including SPS-23/1, K-90, 77-415, UCD-6/7, 2396-8, 88028, Mustard sag, BM-1, and P-98-1. After the third week, several entries including Candle, 88028, UCD-6/7, 77-415, K-90, 2396-8, Mustard sag, P-98-1 and BM-1 had significantly more growth than Toria-A.

Using the criterion of first sharp decline in $R^2$ (Carver et al. 1987), the cluster of BM-1, P-98-1, Mustard sag, and 88028 which after 3 weeks had 4.6 to 5.0 damage ratings and 3.9 to 4.3 number of leaves may represent sources of potential aphid tolerance (Fig. 1a). K-841 was only moderately resistant and had moderate growth and was closely clustered with K-940 and K-1027 whereas the cluster with low damage rating and greatest number of leaves included K-90 and 2396-8. The remaining entries were in several clusters with susceptible damage ratings and low leaf counts.

Test-2 (Table II): The first week damage rating data did not show significant differences among entries. After the second week, the entries were significantly different at $P = 0.0001$ but replications were also significantly different at $P = 0.0002$. The mean comparison among entries showed that no single entry was as heavily damaged as Toria-A. The entries UCD-5/8 and UCD-5/5 were moderately damaged. No other entries were significantly different from K-841. On the third week, damage ratings for the entries were significantly different at $P = 0.0001$. Mean comparison showed that no entry was as badly damaged as Toria-A, and all other entries were considered susceptible or moderately susceptible because they were intermediate in aphid damage between

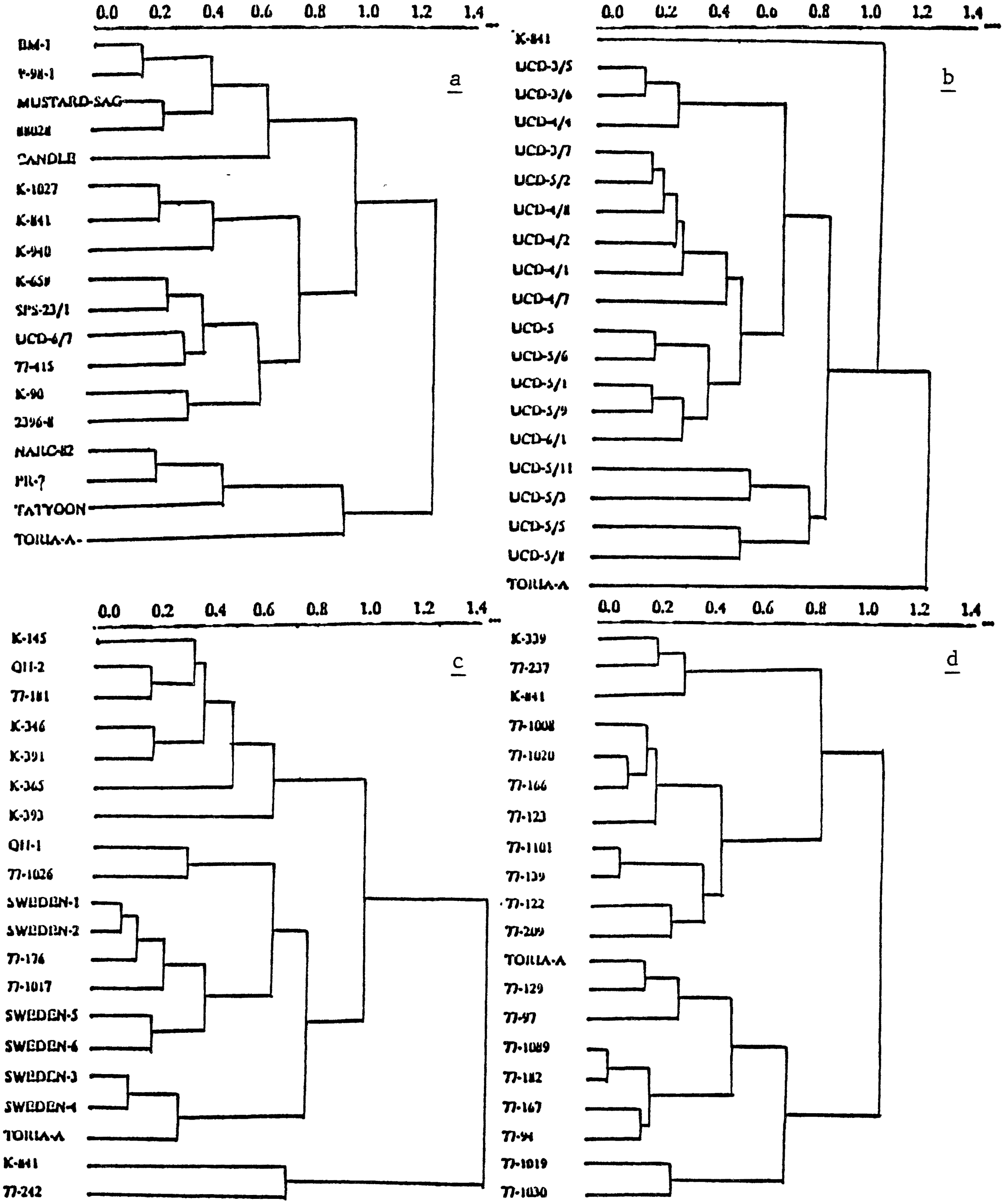

Figure 1. Clustering of Oilseed Brassica's Entries by Average Linkage Method: (a) Test-1, (b) Test-2, (c) Test-3, (d) Test-4

Toria-A and K-841.

The relative growth of entries was not significantly different until the third week $P=0.0001$. UCD-4/7, UCD-5/1, UCD-5/11, UCD-5/3, UCD-5/8, UCD-4/1, UCD-4/8, UCD-5/9, and UCD-4/2 had equivalent or greater growth than K-841.

Cluster analysis (Fig. 1b) showed that several entries were similar in their response to aphid infestation, and all were rated susceptible or moderately susceptible. No entry was clustered with Toria-A or K-841.

Test-3 (Table III): There were no significant differences in damage ratings for entries until the third week $P = 0.006$. All six Swedish entries, 77-1026, QH-1, QH-2, 77-1017, 77-176, 77-181, and K-346 were not significantly different from Toria-A. QH-2, 77-181, and K-346 were intermediate and not significantly different from Toria-A nor from K-841. The entries K-393 and 77-242 were moderately resistant and not significantly different from K-841 in aphid damage.

Relative growth of the entries was not significantly different until the third week of infestation ($P = 0.003$). All entries with exception of K-365 and K-841 had limited growth and leaf numbers not significantly different from Toria-A.

Cluster analysis (Fig. 1c) indicated several large clusters of susceptible and moderately susceptible entries. Only 77-242 was in a distinct cluster with K-841.

Test-4 (Table IV): Analysis of damage ratings for the first week showed that entries were significantly different ($P = 0.0003$) and replications were also significantly different ($P = 0.006$). The entries 77-129 and 77-97 were as heavily damaged as Toria-A. The entry 77-167 was intermediate in response to aphid damage and all other entries were not significantly different from K-841. The second week damage rating for entries were significantly different ($P = 0.0001$)

and replications were also significantly different (*P* = 0.0001). The entries, 77-182, 77-1019, 77-1030 and 77-1089 were added to those as heavily damaged as Toria-A. All other entries were not significantly different from K-841. Damage ratings in the third week indicated significant differences among entries (*P* = 0.006), with most entries not significantly different from Toria-A. They were highly susceptible to moderately susceptible. The entries 77-139, 77-237, and K-339 were not different from K-841, and were considered to be moderately resistant.

The relative growth of entries was not significantly different until third week of infestation. Only K-841 and K-339 had significantly more leaves than Toria-A.

Cluster analysis of the entries (Fig. 1d) identified 77-1030 and 77-1019 as a highly susceptible group distinct from the other susceptible entries due to their being heavily damaged by the second week. The cluster of moderately resistant entries included K-339, 77-237 and K-841.

Test-5 (Table V): Damage ratings were not significantly different until the second week of infestation (*P* = 0.03). Entries 77-92 and 77-165 were as highly damaged as Toria-A. The entries 77-196 and 77-150 were immediate. All other entries were not significantly different from K-841. After the third week of infestation, the entries K-1086, 77-196, 77-92, 77-165, 77-96 and 77-150 were as heavily damaged as Toria-A. Entry 77-117 was intermediate in aphid damage. All other entries were not significantly different from K-841. There were no significant differences in numbers of leaves.

The susceptible entries were clustered in two groups (Fig. 2a): one included 77-165, 77-92, 77-196, K-1086, and Toria-A and the other one included 77-96,

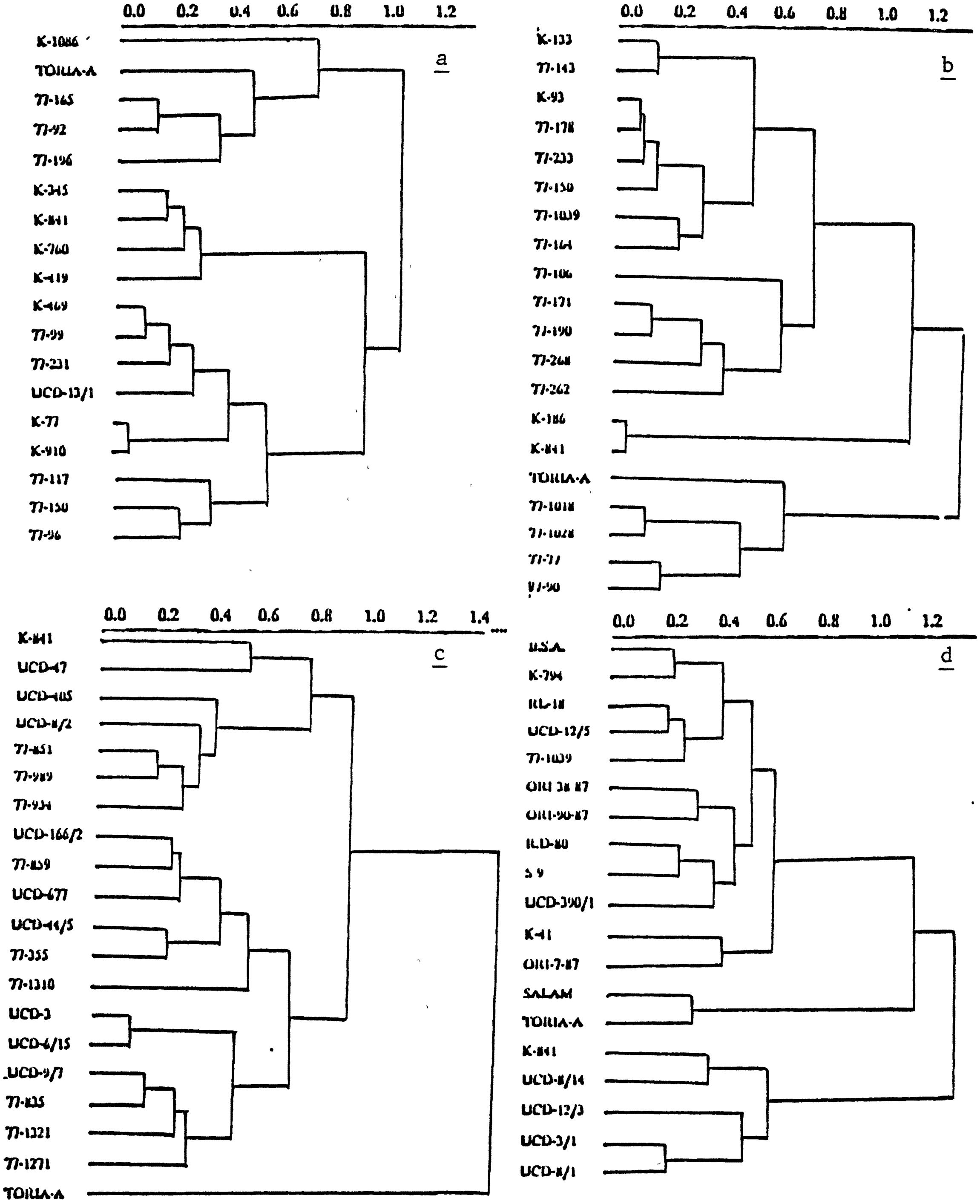

Figure 2. Clustering of Oilseed Brassica's Entries by Average Linkage Method: (a) Test-5, (b) Test-6, (c) Test-7, (d) Test-8

77-150, and 77-117. The entries K-469, 77-99, and 77-231 formed a cluster of moderately susceptible entries. Among the moderately resistant entries, there were two distinct clusters: K-910, K-77, K-345, and K-841. K-760 and K-419 had better damage ratings than K-841.

Test-6 (Table VI): After the first week of infestation, the entries were significantly different in damage ratings (*P* = 0.0001). Toria-A was highly damaged, and the entries 77-143, 77-164, 77-90, K-133 and 77-1028 were intermediate in damage and differed from both Toria-A and K-841. All other entries were not significantly different from K-841. After the second week 77-1018, 77-1028, 77-77, 77-90, K-133 and 77-90 were as highly damaged as Toria-A, whereas all other entries were not significantly different from K-841 (*P* = 0.0004). By the third week, entries such as 77-77, 77-1018, 77-1028, and 77-90 were rated as highly susceptible. The entries K-133, 77-190, 77-171, 77-268 and 77-262 were in the moderately susceptible group. K-186 and K-841 were classified as moderately resistant.

There were no differences in numbers of leaves/plant until the third week when K-841, K-186, 77-262 had significantly greater leaf numbers.

In cluster analysis, the highly susceptible entries formed a distinct cluster with Toria-A (Fig. 2b). Moderately susceptible entries 77-171, 77-190, 77-268 and 77-262 were clustered together. Only K-186 was clustered with K-841 as moderately resistant.

Test-7 (Table VII) Mean damage rating comparisons indicated that no entry was damaged as badly as Toria-A during the first week. After the second week of infestation, Toria-A was again the most heavily damaged and UCD-

44/5, 77-355, 77-1310, 77-859, UCD-677, UCD-405 and UCD-166/2 were intermediate with significantly more damage than K-841 (*P* = 0.001). After the third week, most entries were intermediate in damage, and were rated moderately susceptible. UCD-6/15, UCD-47, and UCD-3 were not significantly different from K-841 (*P* = 0.0001), and were rated as moderately resistant.

The relative growth of entries was not significantly different until the second week of infestation when UCD-8/2, UCD-405, 77-851, 77-934, UCD-47, UCD-166/2 and 77-989 had significantly better growth than other entries which were not different form Toria-A (*P* = 0.008). After the third week, UCD-405 had the greatest number of leaves. UCD-405, 77-851, 77-989, UCD-8/2, 77-934, and UCD-47 were not significantly different from K-841 in leaf number. The other entries were intermediate in growth, but had significantly more leaves than Toria-A (*P* = 0.0001).

Toria-A was not clustered with any other entries (Fig. 2c). Most entries were moderately susceptible in damage, but entries 77-851, 77-989, 77-934, UCD-8/2, and UCD-405 were a cluster of tolerant entries having comparatively less damage and better leaf growth. Among moderately resistant entries UCD-3 and UCD-6/15 were in one cluster, and UCD-47 and K-841 were in another.

Test-8 (Table VIII): One week after infestation, the entries were significantly different in damage ratings (*P* = 0.02). Entries UCD-390/1, S-9, K-794, ORI-90-87, B.S.A, 77-1039 and RL-18 were as damaged as Toria-A. Other entries were significantly less damaged than Toria-A. After the second week of infestation, the entries were different (*P* = 0.0001) and replications were also significantly different. Entries such as Salam, 'B.S.A', K-794, ORI-38-87, 'S-9', 'RL-18', R.D.80, 77-1039 and UCD-12/5 were not significantly different from Toria-A. UCD-390/1, ORI-90-87, ORI-7-87, K-41, UCD-12/3, UCD-8/14, UCD-8/1, and UCD-3/1 were not significantly different from K-841 and were rated moderately resistant. After the third week of infestation, the entries were significantly different (*P* = 0.0001). Entries such as Salam, R.D.80, S-9 and K-794 were as damaged as Toria-A. Entries 'B.S.A', ORI-38-87, UCD-390/1, UCD-12/5, RL-18, ORI-90-87, 77-1039, K-41 and ORI-7-87 were less damaged and were rated moderately susceptible. UCD-8/14, UCD-3/1 and UCD-12/3 were as damaged as K-841 and were moderately resistant. UCD-8/1 was significantly less damaged than K-841 and was rated as resistant.

There was no difference in number of leaves/plant until the third week (*P* = 0.0001). Most entries were significantly better growing than the susceptible standard except UCD-12/3 and Salam.

Toria and Salam, susceptible entries with poor growth, were in a distinct cluster (Fig. 2d). Moderately susceptible entries were in three different clusters: S-9, R.D.80 and UCD-390/1; B.S.A., K-794, RL-18, UCD-12/5 and 77-1039; and with excellent leaf growth - ORI-90-87 and ORI-38-87. The resistant entries UCD-8/1 and UCD-3/1 were clustered adjacent to the moderately resistant UCD-12/3, UCD-8/14 and K-841.

Test-9 (Table IX): Damage rating were not significantly different until the second week (*P* = 0.02). The entries UCD-342, UCD-567 and UCD-467 were as highly damaged as Toria-A. All other entries were not different from K-841. After the third week of infestation, the entries were significantly different (*P* = 0.0003). The entries UCD-567, UCD-342, UCD-467, Altex and Mornoo were not significantly different than Toria-A. All other entries were not significantly different from K-841 and mostly rated moderately resistant.

Relative growth of the entries was not significantly different until the third week of infestation ($P$ = 0.001). UCD-332, UCD-44/3 and PR-269 were not different from UCD-342 which had significantly more leaves than K-841.

The susceptible entries Altex, Marnoo, UCD-467 and UCD-567 were distinctly clustered near Toria-A (Fig. 3a). The moderately susceptible PR-269 and UCD-332 with good leaf growth were clustered together. Moderately resistant entries were in three different clusters: UCD-3/10, UCD-8/4, UCD-44/3, P-61 and K-841; UCD-3/9, UCD-6/9 and UCD-61/2; plus UCD-11/1, UCD-13/1, UCD-11/12 and UCD-29/1. UCD-342 was very distinct from the above clusters because it had the greatest number of leaves and the third highest damage ratings.

Test-10 (Table X): After the first week of infestation damage ratings were significantly different ($P$ = 0.04), but only UCD-341 and Gantyl-5 were as damaged as Toria-A. After the second week of infestation, most of the entries were grouped with K-841 except Toria-A and UCD-341 which were significantly more damaged ($P$ = 0.001). After the third week of infestation, the entries were significantly different ($P$ = 0.001) and replications were also significantly different. Entries UCD-45/2, Gantyl-5, UCD-341, UCD-333, 77-150, UCD-405 and UCD-46/2 were as damaged as Toria-A and were rated moderately susceptible. All other entries were not significantly different from K-841 and were rated moderately resistant. Relative growth of the entries was not significantly different until third week of infestation ($P$ = 0.005). All the entries

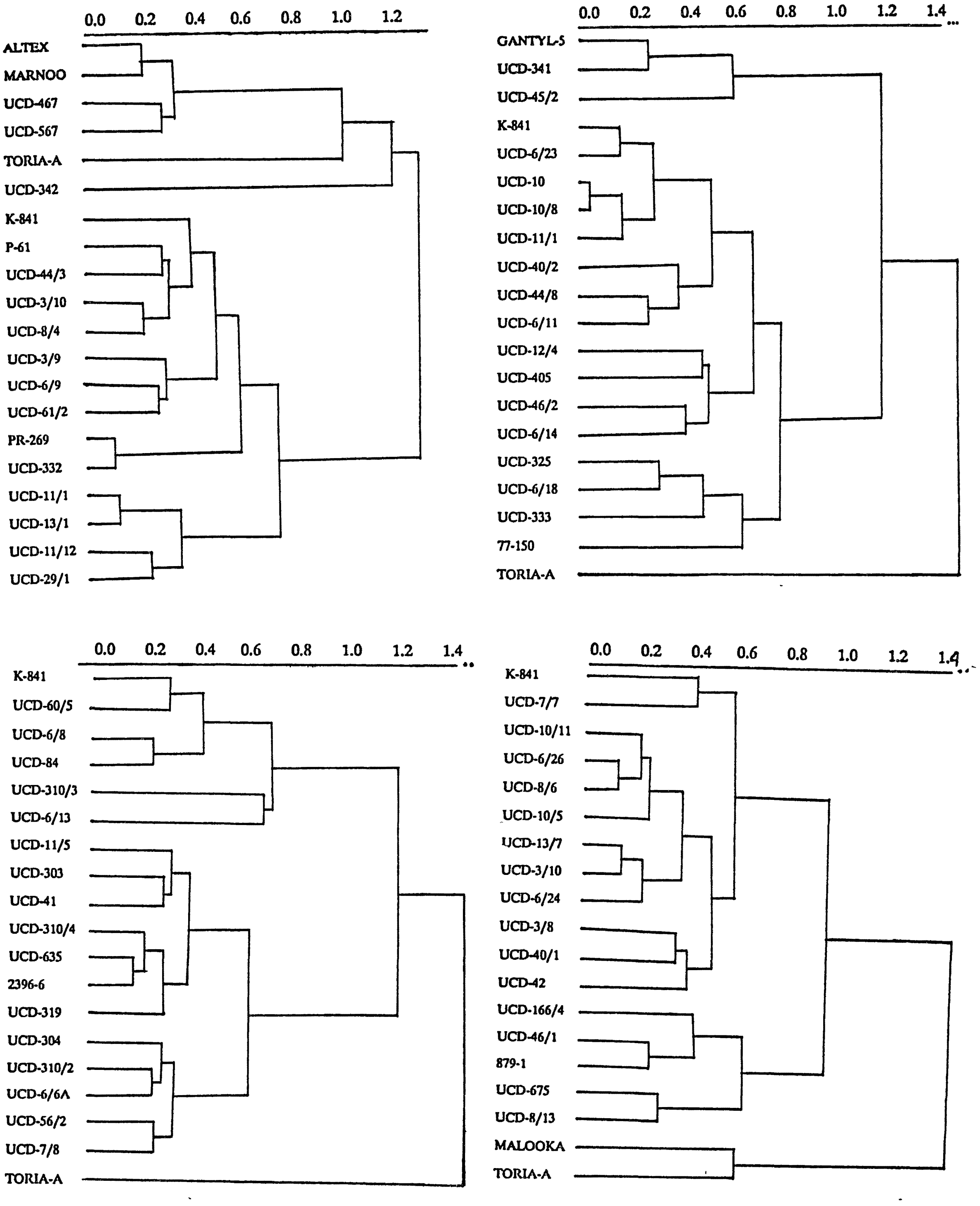

Figure 3. Clustering of Oilseed Brassica's Entries by Averaging Linkage Method: (a) Test-9, (b) Test-10, (c) Test-11, (d) Test-12

were better growing than Toria-A expect UCD-405 and UCD-6/14. UCD-45/2, 77-150 and UCD-40/2 had the most leaves.

Toria-A was in a distinct susceptible cluster (Fig. 3b). The entry, 77-150, was uniquely highest in leaf growth but moderately damaged. Moderately susceptible entries were in three different clusters: Gantyl-5, UCD-341, and UCD-45/2 with heavy damage but near the top in leaf numbers; UCD-6/14, UCD-46/2, UCD-405, and UCD-12/4; and UCD-6/11, UCD-44/8, and UCD-40/2. Moderately resistant entries UCD-10, UCD-10/8 were clustered with UCD-11/12 and then were clustered with K-841 and UCD-6/23.

Test-11 (Table XI): One week after infestation, Toria-A had significantly (*P* = 0.0001)greater damage than all other entries. After the second week of infestation, the entries were not significantly different in damage rating. After the third week of infestation the entries were significantly different (*P* = 0.004). The entries UCD-319, UCD-310/4, 2396-6, UCD-41, UCD-635, UCD-303 and UCD-56/2 were not significantly different from Toria-A in damage and were rated susceptible. The entries UCD-11/5, UCD-7/8, UCD-304, UCD-310/2 and UCD-6/6A were intermediate; neither significantly different from Toria-A nor from K-841. The entries UCD-84, UCD-6/8, UCD-60/5, UCD-310/3 and K-841 were not significantly different from UCD-6/13, the best entry in this test.

The only significant differences in growth for the entries in this test, were because UCD-310/3 was a slow growing entry. After the second and third week of infestation the entries were not significantly different in their relative growth.

Toria-A was distinct from all other susceptible entries (Fig. 3c). Among moderately resistant entries K-841, UCD-60/5, UCD-6/8, and UCD-84 were in one cluster, whereas another important cluster of low damaged entries included UCD-310/3 and UCD-6/13.

Test-12 (Table XII): One week after infestation, the damage ratings for entries were significantly different at (*P* = 0.01). Toria-A was significantly more damaged than the other entries. After the second week of infestation, the entries were significantly different at the (*P* = 0.0001). Entries 'Malooka,' UCD-675, UCD-8/13, UCD-46/1 and UCD-42 were intermediate in damage rating. All other entries were not significantly different from K-841. After the third week of infestation entries were significantly different at (*P* = 0.0001). Malooka was nearly as highly damaged as Toria-A and both were rated susceptible. UCD-675, UCD-8/13 and 879-1 were rated moderately susceptible. UCD-166/4, UCD-46/1, UCD-40/1 and UCD-3/8 were rated moderately resistant. The entries: UCD-10/5, UCD-8/6, UCD-6/24, UCD-6/26, UCD-13/7 and UCD-3/10 were not significantly different from K-841 and were rated resistant.

Relative growth of these entries after the first week of infestation was significantly different at (*P* = 0.03). UCD-10/5, UCD-166/4, UCD-40/1, UCD-3/8, and UCD-8/13 were better growing than the other entries which were not significantly different than Toria-A. After the second week of infestation the entries were significantly different at (*P* = 0.006). The entries UCD-166/4, UCD-3/8, 879-1, UCD-46/1 and UCD-10/5 were better growing than other entries significantly different from Toria-A. After the third week of infestation the entries were different at (*P* = 0.0001). All entries had better growth than Toria-A. UCD-8/6, UCD-8/13, UCD-3/10, UCD-42, UCD-46/1, UCD-6/26, UCD-13/7, UCD-3/8, UCD-40/1, UCD-10/5, UCD-675 and UCD-166/4 produced significantly more leaves compared to K-841.

Moderately resistant entries which had better growth such as UCD-675, UCD-8/13, 879-1, and UCD-46/1 were clustered with UCD-166/4 as a tolerant group (Fig. 3d). The other moderately resistant and resistant entries were in a large cluster.

Test-13 (Table XIII): The damage rating after one week of infestation was significantly different (*P* = 0.002). The entries: 77-1027, 77-104, UCD-323/2 and UCD-6/10, were significantly more damaged than K-841 and they were as damaged as Toria-A. After the second week of infestation, the entries were significantly different (*P* = 0.001). The entries 77-87, 77-1027, 77-101, 77-104, 77-89, UCD-323/2, UCD-6/10 and 77-184 were as damaged as Toria-A, but K-589 and UCD-60/7 were neither significantly different from Toria-A nor K-841. The entries UCD-3/4, UCD-10/4, UCD-189, UCD-9/3, UCD-87, UCD-10/6, and UCD-40/4 were not significantly more damaged than K-841. After the third week of infestation, the entries were significantly different at (*P* = 0.001) and replications were also significantly different at (*P* = 0.0001). Most entries were as damaged as Toria-A. Only entries UCD-10/6, UCD-9/3 UCD-40/4, UCD-3/4 and UCD-10/4 were not significantly more damaged as K-841.

The number of leaves were significantly different after the first week, of infestation (*P* = 0.003). The entries 77-101 and 77-89 had as poor growth as Toria-A. After the second and third week of infestations, there was no significant difference among entries number of leaves.

Susceptible entries were clustered in three distinct clusters. Moderately susceptible entries UCD-10/6, UCD-9/3, UCD-189, UCD-87 and UCD-40/4 were

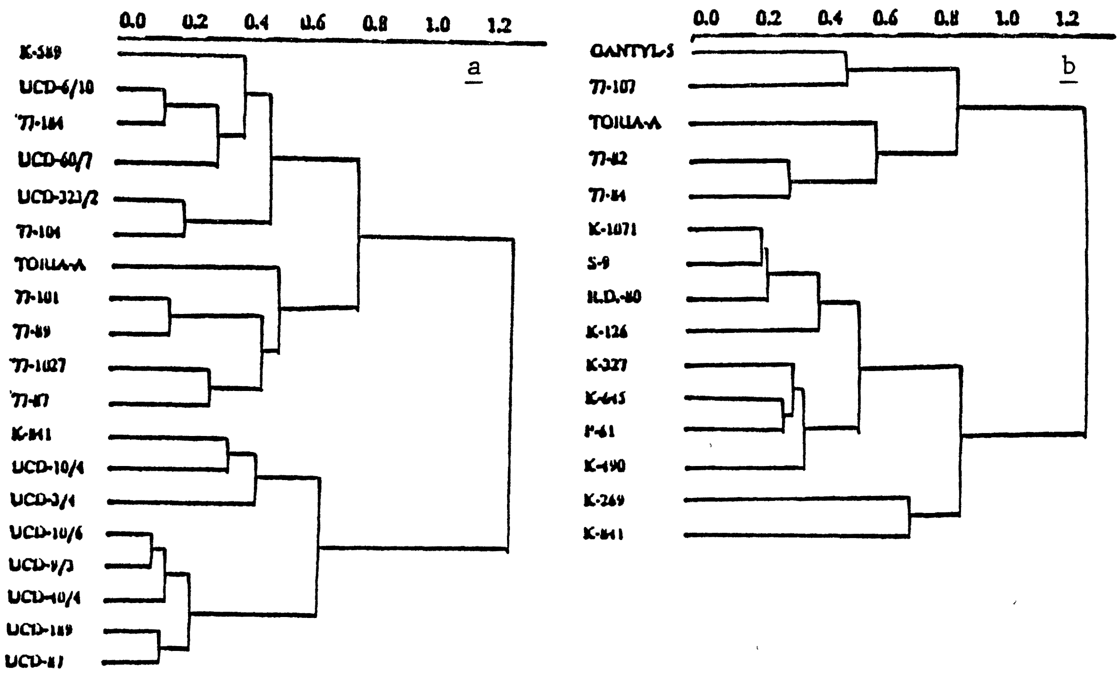

Figure 4. Clustering of Oilseed Brassica's Entries by Average Linkage Method: (a) Test-13, (b) Test-14

closely clustered Fig. 4a). Another cluster of moderately susceptible entries showing some possible tolerance included UCD-6/10, 77-184, UCD-60/7 and K-589. Moderately resistant entries UCD-10/4 and UCD-3/4 were clustered with K-841.

Test-14 (Table XIV): After one week of infestation, the damage ratings were significantly different (*P* = 0.002). No entry was as damaged as Toria-A. The entry 77-107 was intermediate in aphid damage, it was significantly different from Toria-A and K-841. Other entries were not significantly different from K-841. After the second week of infestation, entries were significantly different (*P* = 0.0006). The entries 77-82 and 77-84 were as damaged as Toria-A. Gantyl-5 and K-126 were intermediate in aphid damage and were significantly different from Toria-A and K-841. Entries 77-107, K-269, S-9, R.D.80, K-1071, K-327, P-61, K-645 and K-490 were not significantly different than K-841. After the third week of infestation, there were significant differences among entries at (*P* = 0.0002). The entries 77-82, 77-84, 77-107, and Gantyl-5 were as damaged as Toria-A, and were rated susceptible. K-126, R.D.80, K-1071, and K-269 were rated moderately susceptible. The entries S-9, K-645, P-61, K-327 and K-490 were not significantly different from K-841 and were rated moderately resistant.

The number of leaves for the entries was significantly different the second week after infestation (*P* = 0.0006). The entries P-61, K-490, 77-107, K-645, R.D.80 and K-126 had significantly more leaves than K-841 and Toria-A. K-841 and Toria-A were not significantly different. After the third week of infestation, the entries were significantly different (*P* = 0.0001). The entries K-645, K-126, K-490, S-9, R.D.80, K-327, K-1071, P-61 and 77-107 were significantly better growing than K-841. Whereas, Gantyl-5 and K-841 were better growing than Toria-A.

Susceptible entries 77-82 and 77-84 were clustered, somewhat distinctly with Toria-A (Fig. 4b). Another cluster of moderately susceptible entries which showed some tolerance included K-1071, S-9, R.D.80 and K-126. Moderately resistant entries such as K-645, P-61, K-327, and K-490 were clustered distinctly from K-841 and K-269.

## Discussion

Generally in the process of crop germplasm screening for resistance against insects, a single final damage rating is taken when the susceptible plants are dead or heavily damaged (Painter & Peters 1956). But for some crops it is still questionable when screening for resistance against insects as to when damage data should be taken. The major purpose for the three ratings at one-week intervals was to make sure that any entry with pseudo-resistance should not be selected on the basis of a single recording and to determine the earliest and best single time for plant damage data recording in future oilseed brassica screenings against turnip aphid.

After the first week of infestation, there were not many differences among entries in plant damage ratings. Toria-A, the susceptible standard, had an average damage rating of 2.8 in the 14 tests. Overall there were only 16 entries which had damage not statistically different from Toria-A at the end of one week. The moderately resistant standard, K-841 had an average damage rating 2.1 and there were 147 entries which were not significantly different from K-841.

After the second week of infestation, differences among entries in damage ratings had increased. Toria-A had an average damage rating of 4.5 and there were 45 entries which were not statistically different from Toria-A in damage ratings. K-841 had an average damage rating of 2.5 and there were 146 entries which were not statistically different. Also, there were 47 intermediate entries between Toria-A and K-841.

After the third week of infestation, Toria-A had an average damage rating of 5.7 and in several tests all plants of Toria-A and some entries were dead. There were 93 entries which were as heavily damaged as Toria-A. K-841 had an average damage rating of 3.1 and there were 88 entries which were not statistically different and therefore deserving of more study. There were 57 entries which were intermediate between Toria-A and K-841, but these would be of little interest in a turnip aphid resistance program.

The damage ratings for entries were statistically different ($P > 0.05$) in 11 of 14 tests after one week of infestation. After the second week of infestation, 12 of 14 test entries were statistically different and after 3 weeks all 14 tests showed significant differences among entries. Number of leaves per plant for entries was significantly different for only 3 of 14 tests after one week of infestation. After the second week of infestation, 4 of 14 tests had significant differences in leaf numbers among entries, but after 3 weeks, 11 of 14 tests had significant differences in numbers of leaves per plant. From these results we can conclude that the third week after infestation is the best time to record damage ratings to differentiate among susceptible and resistant entries on the basis of leaf numbers and plant damage.

Results based mostly on third week damage rating showed that damage to 93 entries was not significantly different from Toria-A in the different tests. Among susceptible entries 83 were from *B. juncea*); 16 (*B. napus*); four (*B. campestris*); four (*B. hirta*); and one (*B. carinata*). Among the 230, 60 entries were considered to be moderately resistant, because their damage ratings were not significantly different from K-841 and they had ratings of less than a 4.0. Among these moderately resistant entries, 52 were *B. juncea*, one *B.* campestris, two *B. carinata*, and five *E. sativa*. The other 62 entries were considered to be moderately susceptible because they were significantly less damaged than Toria-A but had mean damage ratings greater than 3.9.

Among the tested species, all entries of *B. napus*, *B. hirta* and *B. campestris* were susceptible; whereas, moderately resistant entries were mainly from *B. juncea*, *E. sativa*, and *B. carinata*. Singh et al. (1965) mentioned that maximum damage occurred to *B campestris* var. sarson and lowest to *B. napus*. Jarvis (1970) found that PI 171538 (*B. napus*) was resistant, whereas in our case no entry of *B. napus* was found to be even moderately resistant. Pathak (1961) noted that *B. juncea* was more resistant to *L. erysimi* than *B. campestris* var. brown sarson. An entry, RL-18, reported moderately resistant by Indian workers was found to be susceptible in our results. In my results, *E. sativa* entries were moderately resistant, but Jarvis (1970) did not find any resistant material in *E. sativa* accessions, but these plants showed some tolerance to turnip aphid. Singh et. al. (1965) also observed tolerance to *L. erysimi* in *E. sativa*. I concluded that the differences in results of different investigators are due to variations in plant material, testing conditions, or the aphid populations used.

# CHAPTER IV

# FIELD SCREENING OF OILSEED BRASSICA GERMPLASM FOR TURNIP APHID RESISTANCE

## Introduction

Traditionally, the germplasm of oilseed brassicas has been screened for resistance to aphids in the greenhouse or laboratory (Jarvis 1970, 1982). However, the utility of greenhouse/laboratory screening data in the field may be limited due to: 1) The population to which the plants are exposed is either too high for moderately resistant cultivars to survive or too low to differentiate between resistant and susceptible cultivars; 2) The greenhouse/laboratory screening is generally with a culture derived from a genetically restricted base, whereas in the field the population may be comprised of genetically variable individuals; 3) laboratory greenhouse screening is generally restricted to one or two initial growth stages of the plant. Greenhouse results may be less useful because resistance in plants may vary with the growth stage (Dunn 1977, and Dodd & van Emden 1979). For example Palmer (1960), Margetts (1963), and Lamp (1965) found 'Aphis Resistant Rape' (a fodder cultivar) was resistant to cabbage aphid at the vegetative stage but not at the flowering stage. Dunn & Kempton (1969) also reported shifts in the relative resistance of 'Aphis Resistant Rape' to cabbage aphid at flowering stage. Though such shifts in resistance levels have not been reported in oilseed brassica against turnip aphid, Prasad & Phadke (1980) found the highest aphid population at flowering stage and concluded that flowering behavior and maturity period for different cultivars play a crucial role in influencing the aphid population increase. This may be a good time for maximum differentiation among entries for resistance to turnip aphid. Also, availability of nutrients and water for the plants in the field may affect the expression of resistance to aphids in oilseed brassicas (Ram & Gupta 1988). The results of field screening are probably more dependable for identifying sources of resistant germplasm to be used for breeding resistant cultivars. A cultivar selected in field screening might also be useful for commercial production. The objective of this study was to screen available oilseed brassica germplasm against field populations of aphids.

Keeping the above factors in mind, all entries screened in the laboratory, where sufficient seed was available, were also screened in the field for turnip aphid resistance during 1988-89, at the NARC, Islamabad, on the northern side of Pakistan at 33.40°N, 73.08°E and 550 m above sea level. The same trial was repeated at the Agricultural Research Institute (ARI), Tandojam, Sind, on the southern side of Pakistan at 25.44°N, and 68.41°E and 25 m above sea level where heavy infestations generally occur, but in 1988-89 there was not a sufficient aphid infestation for differentiation among entries; therefore, only the results of field testing at NARC are reported. The major objective of this study was to screen available oilseed brassica germplasm for sources of field resistance against turnip aphid, and to determine relative value of laboratory screening efforts as a means of identifying entries that are resistant in the field.

## Materials and Methods

Oilseed brassica entries with sufficient seed were obtained from the Oilseed Program, NARC. These 166 entries with resistant standard K-841 were available for planting at two different sites at NARC, Islamabad, and ARI, Tandojam, Sind. Plot size for each entry was 5 m long and 1.8 m wide with three rows spaced 60 cm apart. Plant to plant distance was approximately 10-15 cm which was achieved by thinning at the two-leaf stage. The entries were planted in a randomized complete block design with two replications at each site. The blocks were separated by a 5 m strip of bare ground. One border row of 'Tower' was planted on each side of the Block. Each block was 20 plots wide with a one-meter bare ground space between ranges. Fertilization was applied at 60 kg N and 30 kg P per ha at planting time. Plots were irrigated once before and twice following planting.

Ten adjacent plants in the middle row of each entry were tagged for recording plant damage data leaving a few plants from the border. Each plant was scored for damage rating as well as growth stage (vegetative, budding, flowering, pod set or seed maturity). Plant infestation and damage was scored from 1-6 by the following rating scheme: 1) Highly Resistant = Healthy leaves, no chlorosis, no curling of leaf margins, or only alate aphids on flowers; 2) Resistant = Leaf margins curled, chlorosis, or alate aphids and a few young nymphs on the inflorescence; 3) Moderately Resistant = Leaves curled and increased chlorosis, or scattered small aphid colonies on the inflorescence; 4) Moderately Susceptible = Leaves more curled and tending to be cup-shaped, or one to 8 cm of the inflorescence covered with aphids; 5) Susceptible = Leaf rolling, general discoloration and necrosis of leaves, or 9-16 cm of the inflorescence covered with aphids; and 6) Highly Susceptible = Leaves or whole plant dead, or more than 16 cm inflorescence covered with aphids. The observed data for the growth stage of the each entry, such as, vegetative, budding, flowering and pod formation was transformed to quantitative values where vegetative = 1, budding = 2, flowering = 3, pod formation = 4. The value assigned for pod formation became 5 if that plant was setting pods on the previous recording date. The value was adjusted to 6 if the plant had been setting pods on two previous recording dates. Data from a particular replicate were recorded on the same day. All entries were rated four times in the season on Oct. 13, 14; Oct. 30, 31; Nov. 14, 15 and Dec. 10, 11, 1988, but the natural aphid population was low during the first three recording dates. No artificial infestation was done. During the fourth recording the aphid population was near its peak, but entries were at different growth stages. The damage rating data for the fourth rating were analyzed by GLM and the entry mean comparison was done by LSD (SAS Institute 1985). LSD was used because of the specific interest in identifying the least damaged entries which were not different than K-841. A regression analysis was also done on the available data of 166 different entries at their respective growth stage and plant damage when the aphid population was at peak. This model helped to investigate the type of relationship between plant growth stage and plant damage.

# Results

During the start of the season, the aphid numbers were low, and there was no damage to most of the entries. During the second data recording, aphid numbers were still low and most of the entries were not damaged with exceptions of B. napus entries such as 'Tatyoon', 'Salam', 'Ganyou-5'. Most of the B. juncea and E. sativa entries were at the bud stage whereas B. napus and B. carinata were still in the vegetative stage. On the third sampling date, most of the entries were still only slightly damaged, but there were increased damage ratings for most B. napus and B. carinata entries except UCD-310/3. Most B. juncea entries had started flowering, but other entries were still in the vegetative stage. For the fourth data recording time, the aphid population was near its peak and most of the entries were heavily damaged. Analysis of the data for the fourth damage rating showed that the entries were significantly different at $P = 0.0001$. Mean comparison by LSD showed that 91 entries (Table XV) were not significantly different from the most damaged entry, R.D.80, which had a damage rating of 6.0. The damage rating range for these entries was from 4.4 to 6.0; all these entries were considered to be susceptible, but the intensity of damage was different. There were 62 entries which were not significantly more damaged than K-841 (2.4) (Table XV).

Because our main objective was to find good sources of resistance, the group of 21 least damaged entries on the fourth date (rating range 1.31- 3.20) was of most interest. Entries belonging to different species are: 3161-3, K-427, K-706, K-967, and K-841 - E. sativa; UCD-442/5, UCD-87, UCD-12/5, UCD-310/2, ORI-63-87, UCD-332, 77-851 and UCD-42 - B. juncea; UCD-310/3, 1309-1, UCD-29/1 and 77-1271 - B. carinata; B.S.A. and K-963 - B. campestris; and 1271-2 and Westar - B. napus. These entries represent all five important oilseed brassica species. They also differ in their maturity behavior in that B. napus and B. carinata are late maturing groups as compared to B. juncea, B. campestris, and E. sativa. Maturity time also varied within species.

Most of the entries were in the reproductive stages by the fourth sampling date. Only 13 entries were at bud stage, six were blooming, and 147 were setting and/or maturing pods. Among these 147, 61 had matured most seeds, 73 were setting pods, and 13 had just begun pod set. The analysis showed that there was a quadratic relationship between growth stage and damage rating ($R^2$ = 0.56). The model was: damage rating (R4) = 7.24 - 2.53(S4) + 0.38($S4^2$). From this model the predicted damage rating value was calculated for each entry with the prediction interval set at 90%. For most entries, the observed damage rating fit within the 90% interval. By fitting the model about 82 entries, had observed damage rating of less than predicted value, but most of them were within 90% confidence interval. There were 13 entries which had lower damage ratings than expected and were outside the 90% prediction interval relative to their maturity stage. These entries with their damage rating and growth stage were 3161-3 (1.3, 4.2), K-427 (1.4, 4.9), K-706 (1.6, 4.3), UCD-442/5 (1.7, 4.1), UCD-87 (1.7, 4.5), UCD-310/2 (2.3, 5.4), K-841 (2.4, 4.1), UCD-332 (2.8, 4.8), and 77-851 (2.8, 5.0), UCD-10 (4.0, 6.0) and UCD-6/15 (4.3, 5.9). Eleven of 13 entries were among the least damaged group by LSD mean comparison. UCD-10 and UCD-6/15 were in earlier maturing groups and had higher damage ratings.

## Discussion

Ninety-one entries from the total of 166 entries were highly to moderately damaged by turnip aphids. These entries belong to *B. campestris*, *B. carinata*, *B. juncea*, and *B. napus*, whereas there were 62 entries, which were not significantly different from K-841. Among these 62 entries, 21 entries were in the least damaged group, but no entry was found immune or having a level of resistance significantly higher than K-841. But, higher levels of resistance may not be desirable because they may impose selection pressure and lead to aphid biotypes virulent to the resistance source. The 21 least damaged group of entries represented the mentioned four brassica species, *B. campestris*, *B. carinata*, *B. juncea*, *B. napus*, plus *E. sativa*. All entries of *E. sativa* tested were resistant in the field, which was contrary to the laboratory observations of Jarvis (1970). He reported an intermediate level of resistance in *E. sativa*. In my results, it is difficult to associate resistance or susceptibility with a specific *Brassica* species, except with *E. sativa*. Pathak (1961) said that *B. juncea* was more resistant than *B. campestris*, var. brown sarson to the turnip aphid. Also Singh et al. (1965) reported the maximum damage by the turnip aphid occurred to *B. campestris* var sarson, and lowest fecundity and least damage to *B. napus*. Prasad & Phadke (1980) reported that the aphid population was highest on yellow sarson, brown sarson, and toria varieties of *B. campestris*; lower on *B. juncea* (rai); and lowest on *B. nigra*.

These entries belong to different species, and they differ in their maturity time at the time of the fourth damage rating, though most of them were at pod filling stage, many at initial pod formation or flowering stage, but a few at budding stage. According to the best fitted quadratic model, the entries at pod filling stage seem to be more damaged as compared to entries at budding or initial flowering stage. But still there were some resistant entries which had a lower damage rating than expected within the 90% confidence interval in different growth stages mentioned in the results. The entries which were not exposed to maximum aphid population at later developmental stage, such as UCD-310/3, 1309-1, 1271-2, UCD-29/1, 77-1271 (B. carinata) need to be retested. It is possible that the entries which were resistant in the seedling or vegetative stages may not be resistant at flowering or post-flowering stage as 'Aphis Resistant Rape' cultivar was resistant before flowering stage to B. brassicae, but not after flowering began (Lamp 1965). The entries at pre-flowering stage may have escaped from heavy infestation (Prasad & Phadke 1980). The late flowering varieties have been observed to escape a peak portion of the aphid infestation during the flowering period. Late flowering behavior of the host plant varieties may also influence the population dynamics of aphids.

# CHAPTER V

# EVALUATION OF OILSEED BRASSICA IN THE LABORATORY AT OKLAHOMA STATE UNIVERSITY

## Introduction

After the preliminary screening, 49 entries which had some important agronomic characters or showed resistance in the laboratory, in the field or both were selected for further intensive testing for resistance. Eruca sativa entries, except K-841, were excluded. Seeds of these entries were brought from the NARC to Stillwater, Oklahoma. Entries which were resistant against turnip aphid populations from the NARC may not be resistant to turnip aphid populations from other geographical regions within a country or in other countries. Dunn & Kempton (1972) collected cabbage aphid populations from different areas in England, and determined the rate of reproduction of apterae from each locality on seven resistant and one susceptible clone. They reported that biotypes might exist in England which differ in their reproductive capabilities on a specific brussels sprouts clone. Lammerink (1968) also reported a new biotype of cabbage aphid on the basis of plant damage to 'Aphis Resistant Rape' which was resistant to other cabbage aphid populations. The main objective of these tests were to intensively evaluate the selected entries for resistance against a turnip aphid population obtained from Lane, Oklahoma.

## Materials and Methods

The 49 entries were initially tested in an unreplicated planting in the growth chamber at the Controlled Environment Research Laboratory (CERL) of the Oklahoma Agricultural Experiment Station, Stillwater. Twenty two entries, including two standards (Toria-A and K-841), were planted in 50x35x10 cm plastic trays filled with sandy soil. The tray was divided into eleven 45-cm rows. Ten plants of each entry were planted per half row (20 cm) by placing 2 seeds in a 1/2 cm deep hole made at equal distances of two cm intervals. These plants were thinned to one plant per hole after emergence. After planting, the trays were maintained in a growth chamber with 25°C temperature and 16:8 h light:dark cycle. When at the 2-leaf stage, each plant was infested with 5 to 10 aphids and the trays were covered with plastic cages so the aphids could not escape. After one week of infestation, damage ratings were recorded on five plants of each entry, starting from the end of the row in the center of the tray. Data were recorded for 3 consecutive weeks at one-week intervals. The mean damage rating with standard deviation of each entry is given in Table XVI.

After the single replication evaluation, 18 entries were selected for further testing on the basis of their performance in all previous testing in the laboratory and field at NARC, Islamabad, and at OSU. The entries were divided into two sets each with nine entries to test them in two separate Latin square design tests. Each entry was planted in an individual cup. These nine entries plus the two standard entries were transplanted in a 11x11 Latin-square design in (50x35x10 cm) plastic trays filled with sandy soil, where plant to plant distance was 2.5 cm.

Each test was replicated twice. When these entries were at the two-leaf stage, each tray was infested by putting aphids evenly on the inside of the cotton cloth cage cover, placing the cages on the trays, and tapping the cover.

Aphids were counted on each plant after 8 and 24 h to determine the preference for initial settlement. Total aphid numbers in first test were comparatively low, so numbers were adjusted as a proportion of the susceptible standard Toria-A (Table-XVII). After one week of infestation, individual plants were rated for leaf growth and damage. Ratings continued at weekly intervals for three weeks. Damage rating data were analyzed using SAS and mean comparisons utilizing DMRT protected by a $P \leq 0.05$ F value ANOV (SAS Institute 1985).

## Results

### Single Replicate Testing

Of 49 entries in the unreplicated test, 15 were heavily damaged with plants being dead after the third week of infestation (Table XVI). Twelve entries had damage ratings of 5.8 to 5.0, and were classified as susceptible and nine entries with damage ratings of 4.8 to 4.0 were placed in the moderately susceptible category. Entries receiving a damage rating of 3.6 to 3.0 were P-61, UCD-10/5, UCD-13/1, UCD-13/7, UCD-310/3, UCD-10/15, UCD-46/1, UCD-12/4, and UCD-9/7 were considered moderately resistant. In the resistant category with a damage rating of 2.4 to 2.0 were UCD-8/14, UCD-8/1, K-841, UCD-11/1, and UCD-3/9.

## Latin Square Design Tests

Aphid Numbers. The entries in Test-1 (Table XVII) were not significantly different at $P \geq 0.05$ for preference by turnip aphids whereas replicates were significantly different after 8 and 24 h infestation. In Test-2, when the aphids were counted after 8 h of infestation, the entries, rows and columns within replicates, and replications were significantly different at $P \geq 0.05$. UCD-13/7 had the highest aphid count and 77-1271, UCD-13/1, UCD-10/15, UCD-310/3 were not significantly different from UCD-13/7 (Table XVIII). The entries UCD-6/24, UCD-44/3, UCD-12/4, Toria-A, UCD-6/23, and K-841 had significantly lower aphid counts than UCD-13/7. Aphid counts were still significantly different for replication and entries after 24 h of infestation. The mean comparison among entries showed that 77-1271, UCD-13/7, UCD-310/3, UCD-10/5, UCD-6/23, and Toria-A were more preferred as compared to other entries. UCD-13/1, UCD-12/4, UCD-6/24, UCD44/3, and K-841 had significantly fewer aphids after 24 h of aphid infestation than most preferred entries 77-1271. Therefore a shift was seen in aphid populations between 8 and 24 h. They moved from UCD-13/1 during this interval. The entries, UCD-6/23 and UCD-44/3, were in the less preferred group after 8 h infestation, but later on they had higher aphid numbers than previously. K-841 was the least preferred entry in both tests.

Damage Rating. Ratings for entries and replicates in Test-1, (Table XVII) were significantly different after one week of infestation. Mean comparisons showed that no entry was as heavily damaged as Toria-A. Other entries were still not significantly different from K-841 except UCD-8/1 which was significantly less damaged. After the second week of infestation, Toria-A again showed more damage than other entries, and UCD-46/1 and 77-1321 were different than the UCD-8/1 entry. The third week damage rating analysis showed that entries and replications were significantly different. All plants of Toria-A were dead. Next to Toria-A was 77-1321 with a 3.3 damage rating and significantly more damaged than the other entries. The entries UCD-9/7, UCD-46/1, UCD-3 UCD-8/1, UCD-11/1, UCD-3/9, and UCD-60/5 were not significantly different from K-841. Only UCD-8/14 (2.0) was significantly less damaged than K-841.

Damage ratings for entries in Test-2 showed that UCD-44/3, UCD-10/15, and Toria-A were significantly more damaged than K-841. After the second week, Toria-A and UCD-44/3 were the most heavily damaged entries, whereas UCD-13/7 and UCD-10/15 were intermediate. All other entries were less damaged and not significantly different from K-841. Analysis of the third week damage ratings showed that UCD-13/7, UCD-44/3, and UCD-10/15 were as damaged as Toria-A, whereas 77-1271 was intermediate. The entries UCD-310/3, UCD-12/4, UCD-6/23 and UCD-6/24 did not have a significantly greater damage than K-841. UCD-13/1 was significantly less damaged than K-841.

I concluded that entries UCD-46/1, UCD-3, UCD-3/9, 77-1321, UCD-9/7, UCD-11/1, UCD-8/1, UCD-60/5, and UCD-8/14 were moderately resistant to turnip aphid, whereas in Test-2 the entries UCD-44/3, UCD-10/15, and UCD-13/7, were susceptible. 77-1271 was moderately resistance but statistically different from UCD-310/3, UCD-12/4 and K-841. UCD-6/23, UCD-13/1 and UCD-6/24 were resistant.

# Discussion

Among the 49 entries tested at the CERL, 36 had damage ratings of 6.0-4.0 and were seriously damaged during the 3-week infestation period. Only 13 entries had damage ratings between 2.0 and 3.9 and were rated as moderately resistant to resistant. The high aphid number used in these tests helped to narrow down the entries for further intensive testing.

Among the 12 least damaged entries, 11 were B. juncea with UCD-310/3 the exception. These entries showed a variation in their response during laboratory and field tests. Among the B. juncea entries, UCD-3, UCD-11/1, UCD-3/9, UCD-60/5, UCD-8/14, UCD-12/4, UCD-6/23, UCD-13/1, and UCD-6/24 were heavily damaged in the field at the post-vegetative stage. UCD-44/3 and UCD-13/7 were more damaged in laboratory, but in field tests UCD-44/3 was moderately susceptible and UCD-13/7 was moderately resistant, but significantly more damaged than K-841. There is a great need to determine the cause of this variation. It may be result of the breakdown of the resistance with plant growth stage as Lamp (1965) reported that 'Aphis Resistant Rape' was resistant at vegetative stage but not in the flowering stage or later. UCD-310/3 (B. carinata) was the best moderately resistant entry selected during this evaluation. It was consistent in resistance to turnip aphid populations from Islamabad, Pakistan, as well as populations from Oklahoma. K-841 (E. sativa), my resistant standard, was also consistently resistant to turnip aphid populations from both locations as well as in field testing. These results are different from

Jarvis (1970) who did not find any resistant entry in *B. carinata* and *E. sativa* species but only PI 171538 (*B. napus*) against turnip aphid in the U.S.A.

As for preference studies, the turnip aphid did not prefer any particular species over the other for initial settlement although Jarvis (1970) reported that alate turnip aphids preferred *B. carinata* and *B. napus* over other brassica species. In my results, turnip aphid populations preferred some entries over others for initial settlement, and K-841 was the least preferred by turnip aphids. There was a shifting trend of turnip aphid populations among the entries over time so there were more aphids on K-841 and UCD 13/1 after 8 h than after 24 h of infestation.

# CHAPTER VI

# SURVIVAL, DEVELOPMENT AND REPRODUCTION OF TURNIP APHID ON OILSEED BRASSICA ENTRIES

## Introduction

The turnip aphid, L. erysimi (Kalt.) is a serious pest on cruciferous crops and vegetables in different countries such as U.S.A (Jarvis 1970, Kennedy & Abou-Ghadir 1979) and India (Bakhetia 1980). In India, Rout and Senapati (1968) reported an average pre-reproductive period of 7.5 days, reproductive period of 9.69 days, post-reproductive period of 1.32 days, and longevity of 18.55 days on radish leaves at an average laboratory temperature of 25.5°C. The average rate of reproduction per day and total reproduction per aphid were 4.47 and 42.6 nymphs, respectively. Landin & Wennergren (1987) studied the rate of population increase ($r_{m}$) for turnip aphids from India in Sweden on 'RLM-198,' a moderately resistant oilseed brassica cultivar (B. juncea) from India, at different temperatures from 5°C to 35°C. The $r_m$ value was highest at 25°C, and survival was 95-100%. Turnip aphids did not reproduce at 5°C, and at 35°C aphids died within 12 days.

Host plant resistance may affect the biology and physiology of the arthropods (Painter 1951). Specifically, antibiosis may affect developmental time, reproduction, and survival (Smith 1989). Kundu and Pant (1968) studied the developmental period, reproductive period, fecundity, rate of reproduction, and longevity of turnip aphids on the variety, yellow sarson, (B. campestris); 'T 83', (B. juncea); and 'T 151' (E. sativa). They reported that these biological parameters were affected by different host plants. Narrang & Atwal (1986) reported that glucosinolates extracted from the leaves of B. campestris, B. juncea, and E. sativa had adverse effects on the survival, development, reproductive period, and fecundity of mustard aphids. The action of glucosinolate extracts from E. sativa at 2%, B. juncea at 3%, and B. campestris at 4% were at par in their effect on all biological parameters of mustard aphids.

Singh et al. (1965) used turnip aphid fecundity as an evaluation of oilseed brassica for resistance by infesting inflorescence of the test plants with four aphids for 15 days. They reported that fecundity was inversely related to resistance. Kennedy & Abou-Ghadir (1979) reported that turnip aphids had a longer pre-reproductive period, fewer progeny and were smaller in size on the resistant cultivar 'Shogoin' than aphids on the susceptible 'Purple Top White Globe' turnip variety.

The objective of these studies were to determine the effect of selected oilseed entries on development, survival, and reproduction rates on the intrinsic rate of increase of turnip aphids. I also wanted to develop and validate a predictive model of aphid population growth on hosts with varying degrees of resistance.

## Materials and Methods

In previous studies (Chapters III, IV & V), I found a few promising oilseed brassica entries with moderate levels of resistant which were damaged less by the aphids as compared to Toria-A. These entries were also tested for possible expression of antibiosis mechanisms. I studied the development time, reproduction, and survival of turnip aphid nymphs on selected moderately resistant and on the susceptible and resistant standards, Toria-A and K-841. The $r_m$ was calculated by the method of Wyatt and White (1977) and an adjusted $r_m$ was calculated by introducing the survival percentage of turnip aphid nymphs on particular entries. The $r_m$ value was used to estimate the turnip aphid increase in a given time on these entries. This prediction model was validated in an experiment in the growth chamber on four entries.

Ten to 15 seeds of 12 oilseed brassica entries: Toria-A, UCD-13/7, UCD-12/4, UCD-11/12, UCD-42, UCD-6/24, UCD-6/13, UCD-44/3, UCD-13/1, UCD-29/1, UCD-310/3, and K-841, were planted in styrofoam cups (8.5 cm x 7.5 cm) filled with sandy soil. After germination, single plants of each entry were transplanted into cups filled with sandy soil. Plants were watered when necessary, and 25% Hoagland's solution was applied once weekly. These plants were grown in a room in the CERL at 25±2°C and sufficient florescent light for plant growth at 16:8 h light:dark photophase. A colony of turnip aphids collected from Lane, Oklahoma, was maintained on the turnip plants in a growth chamber at 25±0.5°C.

When the plants were in the 4- to 5-leaf stage, two alate turnip aphids were caged in clip cages (Puterka & Peters 1988) on the upper side of the third or fourth leaves of each entry. After infestation, plants were transferred to a growth chamber, maintained at 25±0.5°C for 14 h light and 22±0.5°C for 10 h dark. This experiment was conducted in a completely randomized design with 7-10 replications of each entry as explained later in this section. The alate aphids were observed each 12-h interval for reproduction. As soon as nymphs were produced, the adults were removed from the clip-cage. Two to three nymphs were left with the assumption that at least one nymph would survive to reach adulthood. Specific time and date was recorded for each cage on each entry. The nymphs were observed for survival each 12 h. The first nymph to reproduce in a cage was kept; the others were discarded, but the observation recorded as 100% survival for the nymphal period. The time interval from birth of the nymph until it produces a nymph is recorded as time (d) in hours. If the caged nymphs were all missing or dead, the replication was repeated beginning with newly born nymphs as described above. If a leaf started to die, the aphids were transferred to another leaf on the same plant.

For md (the number of nymphs produced by an aphid in the time equivalent to (d)), observations were continued on the new adult aphids, which had developed in the clip-cages, from start of reproduction until completion of the specific time interval (d). For each 12 h period, the offspring in each cage were recorded and removed from the cage with a camel's hair brush. The $r_m$ value was multiplied by a survival factor (log of the proportion of nymphal survival on each entry) to obtain the adjusted $r_m$.

These experiments employed a completely randomized design with unequal replications, due to difference in mortality of nymphs on different entries. The data for d, md, survival, $r_m$ and adjusted $r_m$ was analyzed by GLM with mean separation by LSD (SAS Institute 1985).

For validating the predicted population growth, I selected two moderately resistant entries plus the resistant and susceptible standard. The four entries: Toria-A, UCD-13/1, UCD-310/3 and K-841 were planted in 15 cm diameter plastic pots, with 32 pots of each entry. These plants were grown in a growth chamber at 25±0.5℃ and 22±0.5℃ during 16:8h L:D photophase. When these plants were at the six-leaf stage, they were infested with 10 adult turnip aphids cultured on turnip plants. Aphid counts were made on all entries 5, 10, 15 and 20 days after infestation. Because of the variation in aphid numbers, increase counts were also made after 8, 12 and 17 days on Toria-A; 18, 23 and 26 days on UCD-13/1; 18, 23, 26, 31 and 36 days on UCD-310/3, and 23, 26, 31, and 36 days on K-841 in an effort to obtain a count on the date for the peak number of aphids on each entry. At each count, all remaining plants were rated for damage according to the damage rating scheme described in Chapter III. The observed population after 5 and 10 days of infestation and damage rating after 5, 10, 15, and 20 days were analyzed for mean comparison by DMRT (SAS Institute 1985).

## Results

### Developmental Time

Toria-A had the lowest developmental time from birth to reproduction (d) relative to other entries (Table XIX). The (d) time was significantly longer on K-841 than Toria-A. Entries such as UCD-310/3, UCD-6/24, UCD-6/13 and UCD-12/4 were not significantly different from K-841. UCD-44/3 was intermediate, and significantly different from both Toria-A and K-841.

### Reproduction

The md was significantly highest on Toria-A as compared to other entries (Table XIX). The md on UCD-6/13, UCD-11/12, UCD-13/1, UCD-29/1, UCD-42, UCD-6/24, UCD-13/7, UCD-12/4, and UCD-44/3 was significantly greater than K-841. The md value was lowest on K-841 but UCD-310/3 was not significantly different from K-841.

### Survival

Highest survival was on Toria-A (Table XIX), but eight entries: UCD-42, UCD-44/3, UCD-13/1, UCD-13/7, UCD-11/12, UCD-6/24 and UCD-29/1 were not significantly different from Toria-A. Turnip aphid survival rate was significantly less on K-841, UCD-310/3, UCD-6/13 and UCD-12/4 than on Toria-A.

### Intrinsic Rate of Increase

The intrinsic rate of increase ($r_m$) values were functions of both (d) and md when calculated by the Wyatt & White (1977) formula. The $r_m$ value (0.364) for Toria A was significantly higher than for all other entries (Table XIX). The $r_m$ values were intermediate on UCD-11/12, UCD-29/1, UCD-13/7, UCD-13/1, UCD-6/13, UCD-42, UCD-44/3, UCD-12/4 and UCD-6/24 (0.289 to 0.234). The $r_m$ was lowest on K-841, but UCD-310/3 was not significantly different from K-841.

## Adjusted $R_m$

The $r_m$ value calculated by Wyatt & White (1977) does not require consideration of survival rate of aphids on a particular host but survival may be important (Birch 1948). Survival rate was significantly different on the entries, therefore I adjusted the $r_m$ value of turnip aphid on each entry using the formula: (log survival percentage) + (log md) 0.738/d, and called this an adjusted $r_m$. Toria-A had a significantly higher adjusted $r_m$ value than the other entries. The entries UCD-11/12, UCD-13/7, UCD-13/1, UCD-42, UCD-44/3, UCD-29/1, UCD-6/13 and UCD-6/24 were all in an intermediate group. The entries UCD-12/4, UCD-310/3, and K-841 had significantly lower adjusted $r_m$ values.

## Predictive Model

The calculated $r_m$ of a population is a single value which should be valuable in predicting population growth in a prescribed environment. This value can be used to compare the response of aphid species to environmental conditions. The $r_m$ values were significantly different on the entries for the above experiment. This can be used to predict the aphid population increase on different entries in a given time assuming unlimited resources.

After five days infestation, Toria-A had a significantly higher aphid count than UCD-13/1, UCD-310/3 and K-841 (Table XX). UCD-13/1 and UCD-310/3 were not significantly different in aphid counts, but both had a higher count than K-841. After 10 days infestation, the pattern of aphid numbers changed in that UCD-13/1 had a significantly higher aphid number than UCD-

310/3 and K-841, which were not significantly different. After the 10-day count, comparison of aphid numbers was not possible due to limited host plant resources on Toria-A. The peak aphid population on Toria-A occurred 12 days after infestation (Fig. 4a) and numbers declined rapidly thereafter. The peak aphid population on UCD-13/1 and UCD-310/3 occurred after 18 days of infestation (Fig. 4b, c). Whereas aphid numbers on K-841 peaked after 26 days of infestation (Fig. 4d). These results showed that population growth rate and population carrying capacity was different on these host entries.

After 5 days of infestation, Toria-A had a significantly higher average damage rating than UCD-13/1, UCD-310/3 and K-841, whereas these three entries were not significantly different (Table XX). After 10 days, UCD-13/1 and K-841 had similar damage ratings but were significantly less than UCD-310/3 which had more damage. After 15 days Toria-A plants had almost died, while UCD-13/1 had significantly less damage than UCD-310/3 and K-841. After 20 days infestation, Toria-A plants were dead, whereas UCD-13/1 and UCD-310/3 were moderately damaged, but were significantly higher than K-841. UCD-13/1 plants died after 25 days of infestation; the UCD-310/3 survived up to 31 days and K-841 survived up to 36 days after infestation.

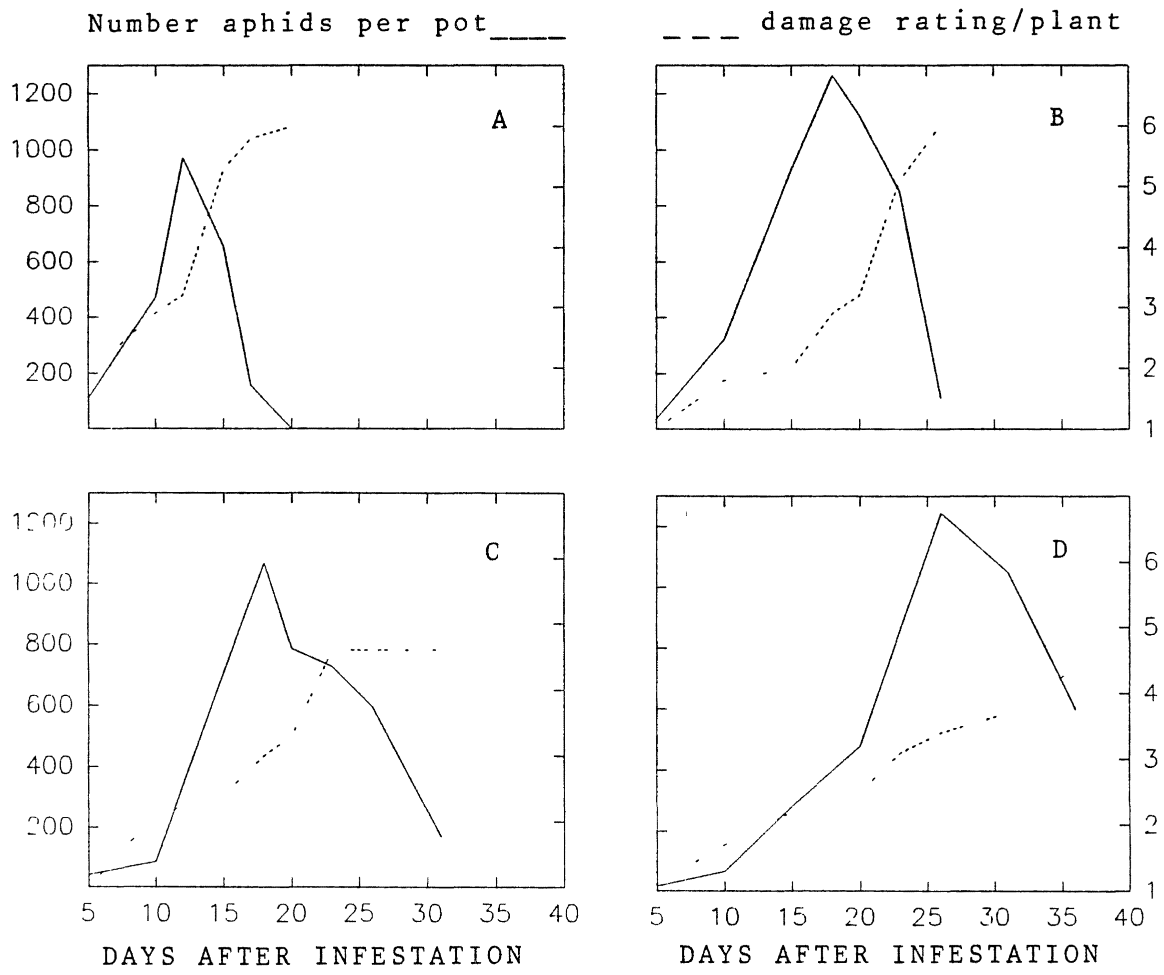

Figure 5. Number of aphids/pot and damage rating/plant over time on (A) Toria-A, (B), UCD-13/1, (C), UCD-310/3, (D), K-841

## Discussion

Plant damage is generally a function of insect population levels; populations which increase earlier will cause plants to show damage sooner. Control measures are mostly applied to keep the pest population low so it will not cause economic damage to crops. Among control measures, resistance also contributes by keeping the crop damage low either by antibiosis, antixenosis, or tolerance. Antibiosis contributes by slowing down the population increase and often delays or prevents the pest from reaching the economic injury level.

The survival percentages for turnip aphids were significantly higher on the susceptible standard Toria-A (B. campestris) as compared to K-841, UCD-6/13 and UCD-12/4. Survival was affected by resistance level of the entry in contrast to the research of Landin & Wennergren (1987) where the survival was 95-100% on leaf discs of RLM 198, a moderately resistant cultivar. Hussain (1983) reported the significant differences in nymphal survival of B. brassicae on different entries of oilseed brassica species; he found the highest on B. napus (87%) and the lowest on B. carinata (46%).

The developmental time from birth to first reproduction (d) may be related to the level of resistance or susceptibility, as high level of resistance delayed the (d) as compared to susceptible entry. Developmental time was significantly less on Toria-A and longer on resistant entries like K-841, UCD-310/3 UCD-6/24 and UCD-12/4. Kennedy & Abou-Ghadir (1979) reported that alatae and apterae took significantly longer prereproductive times on the resistant turnip cultivar 'Shogoin' than on the susceptible 'Purple Top White Globe'.

The reproduction per aphid (md) was significantly higher on Toria-A than on all tested entries. The reproduction was lowest on K-841, whereas UCD-310-3 was not different than K-841. All other entries were intermediate between Toria-A and K-841. Dunn & Kempton (1969) also reported 50% less fecundity on 'Aphis Resistant Rape' by B. brassicae.

The $r_m$ values were also significantly different on the entries. The high $r_m$ value indicated that the turnip aphid has a greater reproductive potential on Toria-A than other entries. The low $r_m$ value on K-841 and UCD-310/3 indicated these entries had considerable antibiosis. Dunn & Kempton (1969) reported that on 'Aphis Resistant Rape', nymphs took about 13% longer to mature; adults had 30% shorter reproductive spans, reduced fecundity, and suffered 40% mortality in their progeny. Root & Olson (1969) reported that different host species and varieties of a species had varying effects on the rate of population increase of cabbage aphid, which was lower on the resistant host, Barbarea vulgaris, as compared to collard, Chinese broccoli and cabbage.

The $r_m$ value I obtained on Toria-A was similar to that reported by DeLoach (1974) on collard, but much lower than the 0.45 $r_m$ value reported by Landin & Wennergren (1987) on leaf discs of moderately resistant 'RLM 198' (B. juncea) at similar temperatures. Phadke (1982) reported $r_m$ values for turnip aphids on different cultivars: 0.206 on T9 (var. toria); 0.202 on Ys-pb-27 (var. yellow sarson); 0.165 on Pussa Bold (var. brown sarson), B. campestris, and 0.155 on BSH-1 (B. juncea) in the field at average minimum and maximum temperature of 8.3°C and 23°C. The $r_m$ values of turnip aphids in different studies might be due to differences in aphid biotypes, different plant varieties and species, but different $r_m$ values for turnip aphid in similar environment on different entries should be due to varying levels of plant antibiosis.

The turnip aphid populations were significantly lower on UCD-13/1, UCD-310/3 and K-841 than on Toria-A; whereas UCD-13/1 had a significantly greater population than UCD-310/3 and K-841 after 10 days of infestation relative to their low $r_m$ values. There was a significant difference in aphid population increase between the resistant and susceptible standard and even among moderately resistant entries. Starks et al. (1972) reported significant differences in greenbug population increases 21 days after infestation on resistant and susceptible cultivars of barley.

The peak aphid population occurred 6 days later on UCD-13/1 and UCD-310/3 6 days than on Toria-A; whereas the peak aphid population on K-841 was 14 days later than Toria-A. The delay in peak population on these entries was attributed to their antibiotic effect on turnip aphids. These entries ranked as follows in their antibiotic affect; K-841 > UCD-310/3 > UCD-13/1 > Toria-A. Tolerance based on damage rating at their peak population on these entries were UCD-13/1 > 310/3 > K-841 > Toria-A. UCD-13/1 (B. juncea) appeared to have more tolerance and less antibiosis than the other two entries. UCD-310/3 (B. carinata) had better antibiosis, whereas K-841 (E. sativa) had better antibiosis and non-preference (Chapter V), but may have less tolerance. Toria-A (B. campestris) did not show any antibiosis or tolerance to the turnip aphid.

## CHAPTER VII

## FEEDING BEHAVIOR OF TURNIP APHIDS ON OILSEED BRASSICAS ENTRIES

### Introduction

The turnip aphid is a serious pest of cruciferous crops. It is a major threat to oilseed brassicas in India and Pakistan. Different studies have been conducted to better understand this insect-plant relationship. Such studies include the effect of sinigrin on host selection behavior of turnip aphid (Nault & Styer 1972) and the effect of glucosinolates present in different oilseed crucifers on the feeding response and biology of turnip aphids (Narrang & Atwal 1985, 1986). Feeding behavior of turnip aphids on oilseed brassicas has not been recorded by electronic feeding monitors.

The feeding monitor developed by McLean & Kinsey (1967) has been used to gain a better understanding of insect-plant relationships and feeding behavior of the greenbug, Schizaphis graminum (Rondani) on wheat (Triticum aestivum L.) (Niassy et al. 1987); barley (Hordeum vulgare L.) (Peters et al. 1988); and sorghum (Sorghum bicolor (L.) Moench) (Campbell et al. 1982). The electronic feeding monitor also provides specific information on feeding activities, their duration, and on the sequence of these activities. The electronic feeding monitor has been used in defining possible differences among resistant and susceptible cultivars of wheat to different greenbug biotypes (Niassy et al. 1987). They reported that the time to beginning of phloem ingestion was greater on resistant than on susceptible wheat, and duration of phloem ingestion was shorter on resistant than on the susceptible wheat genotypes. Niassy et al. (1987) also showed that biotypes B and E greenbug exhibited less baseline, salivation time, fewer number of probes and X-waves, but more phloem ingestion time on the susceptible wheat 'TAM 105' as compared to the resistant 'TAM 107' or 'Largo' x 'TAM 105', respectively.

Nault & Styer (1972) used electronic feeding monitors to study feeding activities of turnip aphids for 4 h on detached leaves of turnip. Their results showed that the salivation, ingestion, and X-waves formed were similar to those produced by Acyrothosiphon pisum (Harris) reported by McLean & Kinsey (1967), but there were two types of probes (feeding episodes): short duration (<60 second) or long duration (>5 minute). They also studied turnip aphid feeding activities on turnip, cabbage, and broad bean leaves which were treated or untreated with sinigrin, to determine the effect of sinigrin on feeding activity of the turnip aphid. They correlated the recorded waveforms with the location of aphid stylets in plant tissue by histological methods. The feeding sequences found were salivation-ingestion (s-i), salivation-x-wave (s-X), and salivation-X-wave-ingestion (s-x-i). For s-i, the stylets were located in the mesophyl parenchyma, xylem, and the phloem parenchyma; for the s-x-i sequence, the stylet tips were found in the phloem, and for the s-x, the stylets were also found in the sieve elements. They reported significant differences in total duration of phloem ingestion on turnip, cabbage and on broad bean leaves treated and untreated with sinigrin.

The objective of this study was to determine the feeding behavior of turnip aphids on oilseed brassica species, and to observe the differential responses of turnip aphids on Toria-A and K-841 standards and on promising resistant oilseed brassica entries.

## Material and Methods

Twelve oilseed brassica entries, including the standards, Toria-A (B. campestris) and K-841 (E. sativa); UCD-29/1 and UCD-310/3 (B. carinata) and UCD-11/12, UCD-12/4, UCD-13/1, UCD-13/7, UCD-42, UCD-44/3, UCD-6/13 and UCD-6/24 (B. juncea) were planted in 8.5/mg with 7.5 dia. styrofoam cups filled with sandy soil. These cups were placed in a room in the CERL with temperatures of about 25°C and a 16:8 h photophase provided by a bank of fluorescent lights. Plants were watered as required and a 25% Hoagland's solution was applied once a week. Plants were in the 3- to 4-leaf stage when used for the feeding monitor studies.

The turnip aphids collected from Lane, Oklahoma, were maintained on turnip plants in a growth chamber at 25°C and 16:8 h photophase. Apterous adult aphids from this culture were used for the feeding monitoring studies. The feeding monitor tests were conducted in a room at the USDA-ARS, Plant Science Research Laboratory. The feeding monitor instrumentation and behavior codes were similar to those used by Niassy et al. (1987) except that turnip aphids make multiple X-waves (a sequence of more than one X-wave) for varying lengths of time before phloem ingestion. This behavior was different from those recorded for greenbugs. There was a one to one relationship between baseline and probe frequencies since a probe by definition is the initial period of high energy flow preceded by a baseline.

The 12 entries were tested in two sets, each set having 6 entries which was run in a Latin-square design, with days as rows, monitors as columns, and entries as treatments. Aphid feeding was monitored for a minimum of 480 minutes in the first set. The second set was limited to 470 minutes and involved some night runs using the same bugs monitored during the day on different entries. The feeding behavior activities were recorded on strip-chart recorders at a paper speed of 0.5 cm/minutes. The data were analyzed using GLM SAS (SAS Institute 1985) for analysis of variance and means for entries were compared using the DMRT test (SAS Institute 1985).

## Results

Since this was the first time turnip aphids were monitored on oilseed brassica, I was interested in observing as many entries as possible among the promising resistance sources and did not repeat the standard entries in the second set. Conservative statistical procedures do not allow pooling the two sets, but I will discuss them together because all the test entries appeared to cause behavior indicative of aphid resistance.

### Baseline

The increased frequencies and increased length of baseline activity is indicative antixenosis. The frequencies of baseline (which is when absolutely no feeding contact was made with the plant) activity were lower for turnip aphids on Toria-A, UCD-13/1, UCD-44/3 and UCD-29/1 as compared to K-841 and the other entries (Table XXI, XXII). The mean duration for baseline by the turnip aphid was 2.4 min on Toria-A as compared to 3.6 min on K-841. On the entries UCD-6/24, UCD-29/1, UCD-44/3 and UCD-42, the mean duration was between Toria-A and

K-841. UCD-310/3 had the same mean duration as K-841, and on the other entries mean baseline duration was more than K-841 (Table XXIII, XXIV). The total baseline duration turnip aphid was 39 min on Toria-A. The total baseline duration was slightly more on UCD-13/1, UCD-29/1 and UCD-44/3 compared to Toria-A, whereas it was 80 min on K-841. On the other moderately resistant entries total baseline duration averaged more than K-841 (Table XXV, XXVI).

### Probes

The frequencies of probes by turnip aphids were similar to the frequencies of the baselines on particular entries because each probe was preceded by baseline activity. The frequency of probes on Toria-A, UCD-13/1, UCD-29/1 and UCD-44/3 were 16 to 18 compared to 26 on K-841. Other entries had 26 to 34 probes (Table XXI, XXII). Mean duration for probes of turnip aphids did not have a wide range and was only 0.8 to 1.0 minutes on the different entries (Table XXIII, XXIV). Total duration in probes was shorter on Toria-A, UCD-13/1, UCD-44/3 and UCD-29/1 (13.6-18.0) as compared to the other entries but differences were a reflection of frequency and not mean duration.

## Salivation

The salivation frequency by turnip aphids was lowest on Toria-A (10.3). This frequency was 50% more on UCD-6/13, UCD-13/1, UCD-44/3, and UCD-29/1 and 100% more on K-841 and most other moderately resistant entries (Table XXI, XXII). The mean duration time per salivation event was almost the same on Toria-A and K-841, and on the other entries. In the first test, total duration for salivation was significantly different at *(P* = 0.05). The total salivation time was significantly lower on Toria-A (92 min) than on K-841 (248 min), and the entries UCD-6/24, UCD-13/7 and UCD-6/13 were not significantly different from K-841. Total duration was not significantly different among entries in the second test, but ranged from 160 to 200 min. In the second test all entries were moderately resistant, and had similar total salivation times to those of the moderately resistant entries in test one.

## Non-Phloem Ingestion

The frequency of non-phloem ingestion by turnip aphids was relatively low for all entries and at least one aphid on each entry did not display this behavior. Mean durations by aphids on the 12 entries were fairly consistent except for UCD-12/4 with the lowest frequency of non-phloem ingestion, and with only two of six aphids displaying this behavior. The mean duration in non-phloem ingestion was shortest on UCD-12/4 and longest on UCD-310/3 (Table XXIII, XXIV).

## X-wave

This unique type of waveform occurs only before phloem ingestion. There were two types of X-waves – single X-wave or many consecutive X-waves which I called single or multiple X-waves, respectively. There were no single X-waves formed on Toria-A, UCD-310/3 and UCD-13/7. Other entries had one to three X-waves (Table XXI, XXII). The mean duration for a single X-wave was not more than one min, it ranged from 0.7 to 1.0 min (Table XXIII, XXIV). The entries in the first test were significantly different in frequencies of multiple X-waves. The frequencies of multiple X-waves were significantly less on Toria-A (1.8) than on UCD-6/24 (7.3). Other entries in test one were intermediate (4 - 5) between Toria-A and UCD-6/24. Multiple X-wave activities on the entries in test two were also intermediate. The mean duration in multiple X-waves was longest on Toria-A (26.8) and lowest on K-841 (1.3). Other entries ranged from 1.8 to 5.8 min.

## Phloem Ingestion

The turnip aphid on the entries in test one were significantly different (*P* = 0.04) in phloem ingestion frequency and mean duration. Phloem ingestion event frequencies were significantly less for Toria-A (1.3) than K-841 (6.2). The highest phloem ingestion frequencies were on UCD-6/24 (7.3), but it was not statistically different from K-841. Other entries in test one were not significantly different than K-841 and Toria-A. The turnip aphids on entries in test two had a range of phloem ingestion frequencies close to K-841. The mean duration of phloem ingestion of turnip aphids was higher on Toria-A (207 min) than on K-841 (23 min) and all other entries in test one were close to K-841 as compared to Toria-A (Table XXIII, XXIV). The phloem ingestion by turnip aphid on all entries in test two had mean durations of phloem ingestion closer to K-841 as compared to Toria-A.

Turnip aphids spent 252 min total time in phloem ingestion on Toria-A whereas it was only 73 min on K-841. The other entries were more like K-841 in phloem ingestion than Toria-A (Table XXV, XXVI). Turnip aphids spent 148 to 190 min in phloem ingestion on UCD-13/1, UCD-44/3, UCD-29/1 and UCD-12/4, whereas on UCD-6/13, UCD-6/24, UCD-11/1 and UCD-310/3 the range was 77 to 121 min and very similar to K-841 in mean and total phloem ingestion; whereas total phloem ingestion time was shortest on UCD-42 and UCD-13/7, with 65 and 34 min.

## Discussion

Baseline events for turnip aphids were 46% more frequent, 50% longer mean duration, and 112% longer total duration on K-841 as compared to Toria-A. Turnip aphids had lower frequencies of probes, salivation, and non-phloem ingestion feeding behaviors on Toria-A. The mean duration and total duration of these activities was also low on Toria-A compared to K-841. Ryan et al. (1987) reported that the total amount of baseline time of greenbug biotypes on resistant wheat plants is double as compared to susceptible wheat plants.

Turnip aphids had 50% more salivation frequency events on K-841 and 37% more total salivation duration on K-841 and 37% more total salivation duration on K-841 than Toria-A. Nielson & Don (1974) also reported salivation time by spotted alfalfa aphids, Therioaphis maculata (Buckton), was significantly longer on resistant clones than susceptible clones.

Turnip aphids had 4.8 times more phloem ingestion events on K-841 as compared to Toria-A, but nine times less mean duration and 3.5 times less total duration in the phloem. Turnip aphids also made more probes and spent less time in phloem ingestion on cabbage leaves and less probes and more time in phloem ingestion on turnip leaves, the preferred host plant compared to cabbage plants (Nault and Styer 1972).

Among moderately resistant entries, such as UCD-13/1, UCD-44/3 and UCD-29/1 were close to Toria-A as compared to K-841 in nonfeeding activity (baseline) and probes of turnip aphid, but there was 30-70% less total phloem ingestion time on these entries than on Toria-A. The selected entries were close to K-841 in baseline, probing and total duration of phloem ingestion.

The greater frequency of probing on moderately resistant entries would suggest that aphids explored these more extensively or were not stimulated to sustain a probe into salivation and phloem ingestion. Data on X-wave and phloem ingestion frequencies showed that aphids were more frequently in phloem ingestion on these moderately resistant entries as compared to susceptible, but spent less total time in phloem ingestion. There were also long X-waves observed in this study in which turnip aphids spent 27 min in multiple X-waves on Toria-A and about 2 min on K-841. There may be a relationship between X-wave and phloem ingestion in both cases in that more time spent in X-wave activity leads to more time in phloem ingestion. Nault & Styer (1972) also observed that turnip aphids took more time (66 min) in the X-wave activity on turnips as compared to cabbage (15 min) during a 4-h observation period.

The feeding behavior studies showed that turnip aphids fed less successfully on resistant plants as indicated by reduced phloem ingestion time and increased non-feeding (baseline), higher frequency of epidermal penetration and more X-waves. The relatively short duration of salivation on susceptible compared to resistant entries was another indication of difficulties that turnip aphids had when feeding on resistant entries. Turnip aphids were more successful in feeding on Toria-A as compared to K-841 and the other selected entries. This indicates that the major expression of resistance was a longer baseline time, greater frequency of probes and shorter duration in phloem ingestion, which would probably contribute to less damage to host plants.

# CHAPTER VIII

# SUMMARY AND CONCLUSIONS

The oilseed brassica are major oilseed crops in Pakistan as well as in many other countries such as Canada, Sweden, China, and India. They are planted on 386,000 ha in Pakistan. The average yield in Pakistan is 0.57 ton/ha, which is lower than most other countries. Importation of vegetable oil is second only to petroleum as a major burden on the Pakistan economy.

Insect pests, especially turnip aphids (Lipaphis erysimi (Kalt)), drastically reduce rapeseed and mustard seed yields in Pakistan. There is a critical need for turnip aphid host plant resistance in rapeseed and mustard. The main objective of the study was to find sources of turnip aphid resistance in rapeseed and mustard germplasm.

In this study 230 entries of rapeseed and mustard were screened in the laboratory, and 166 entries were screened in the field at the National Agricultural Research Center, Islamabad, Pakistan. There were 57 entries which were not significantly more damaged more than K-841, and which had mean damage ratings less than 4.0 in the laboratory screening. In the field evaluation at NARC, aphid damage on 62 of 166 entries was not significantly different from K-841. There was a group of 21 least damaged entries and the mean damage ratings of these ranged from 1.3 to 3.2. Overall damage ratings were low in the field under a natural aphid infestation as compared to the laboratory. During field screening most of entries were at varying pod-formation stages, and only a few still at the budding or flowering stage when the aphid population peaked.

Forty-nine entries selected on the basis of laboratory and field tests were tested against a turnip aphid population from Lane, Oklahoma, at Oklahoma State University, Stillwater, Oklahoma utilizing heavy infestations in trays covered with cages. Among these, 18 better entries were further tested in two 11x11 Latin-square design tests, along with two standard entries in each test. In test-one, the entries UCD-46/1, UCD-3, UCD-3/9, UCD-9/7, UCD-11/12, UCD-8/1, UCD-60/5, UCD-8/14 were significantly less damaged (3.7-2.4) than the susceptible check. In test-two the entries UCD-310/3, UCD-12/4, UCD-6/24 and UCD-13/1 were significantly less damaged (3.1-2.2). Among these 12 entries, 11 entries were B. juncea which had heavy damage in field screening except UCD-8/1. UCD-310/3 (B. carinata) had low damage in all tests in laboratory as well as in the field.

For preference studies, the entries in test-one were not significantly different, whereas in test-two, the entries UCD-6/24, UCD-12/4, UCD-13/1 were not significantly different from K-841, which had the least number of aphids as compared to other entries.

Fecundity, survival rate, and days to maturity of turnip aphids were also studied on UCD-44/3, UCD-42, UCD-13/7 UCD-6/13, UCD-11/12, UCD-13/1, UCD-29/1, UCD-6/24, UCD-12/4 and UCD-310/3 compared to Toria-A and K-841. Fecundity of turnip aphids was significantly lower on UCD-310/3 and K-841. The entries UCD-6/13, UCD-11/12, UCD-13/1, UCD-29/1, UCD-42, UCD-6/24, UCD-13/7, UCD-12/4 and UCD-44/3 were not significantly different among themselves. The survival of nymphs was also significantly different on these entries, and it was lowest on UCD-12/4, UCD-6/13, and K-841. Turnip aphids took fewer days to mature on Toria-A than on UCD-310/3, K-841, UCD-6/24, and UCD-12/4. These moderately resistant entries have a significant antibiotic effect on turnip aphid biology.

The $r_m$ value for turnip aphids was significantly higher on Toria-A than on all other moderately susceptible and moderately resistant entries, whereas it was significantly lowest on UCD-310/3 and K-841. In another experiment among moderately resistant entries, the increase in aphid numbers 10 days after infestation with 10 aphids/plant, aphid counts were significantly higher on Toria-A compared to UCD-13/1, UCD-310/3, and K-841; UCD-13/1 had significantly higher aphid counts than UCD-310/3, and K-841. When limited by host plant quality (damage) turnip aphid numbers on Toria-A peaked on 12th day; on UCD-13/1 and UCD 310/3 they peaked on the 18th day; and on K-841 on the 26th day after infestation of 6-leaf stage plants.

The feeding behavior of turnip aphids was recorded by electronic feeding monitor on 12 entries. There were no significant differences among entries in behaviors such as baseline, probing and non-phloem ingestion, for frequency, mean duration and total duration, but turnip aphids spent significantly more mean duration time in phloem ingestion on Toria-A as compared to other entries. Frequencies and total durations for salivation behavior was also significantly greater for K-841 and some test entries than for Toria-A. There were two types of X-waves in our studies – single X-wave and multiple X-waves, which are an unbroken sequence of X-waves.

It was concluded from this study of screening oilseed brassica for turnip aphid resistance in laboratory and field in Islamabad, Pakistan as well as in Oklahoma, that UCD-310/3 (B. carinata) and K-841 (E. sativa) have the highest level of resistance against turnip aphid. The mechanism of resistance has not been proven but appears to be mostly antibiosis, but tolerance and antixenosis are also important. Other entries also appeared to have moderate levels of antibiosis or tolerance. These findings were supported by the study of intrinsic rate of increase ($r_m$) and feeding behavior monitored by electronic feeding monitors on some of these entries.

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# APPENDIX

# TABLES

# TABLE I

## MEAN DAMAGE RATING AND NUMBER OF LEAVES FOR THE ENTRIES IN TEST 1

| | Damage Rating | | | Number of Leaves | | |
|---|---|---|---|---|---|---|
| Entry | Week-1 | Week-2 | Week-3 | Week-1 | Week-2 | Week-3 |
| Toria-A | 3.4a | 3.8a | 5.7a | 1.8 | 2.0e | 2.5e |
| Candle | 2.2bcd | 2.9bcd | 5.5ab | 2.4 | 2.9a-d | 3.6a-d |
| Tatyoon | 2.1cd | 2.5def | 5.4ab | 1.7 | 2.0e | 2.5e |
| NARC-82 | 2.6b | 2.9bcd | 5.1abc | 1.9 | 2.4de | 2.9cde |
| Mustard-sag | 2.6b | 3.4ab | 5.0abc | 2.4 | 3.4ab | 4.1a |
| PR-7 | 2.4bc | 2.9bcd | 5.0abc | 2.1 | 2.4de | 2.6de |
| 88028 | 2.2bcd | 3.3abc | 4.9a-d | 2.3 | 3.2abc | 3.9abc |
| BM-1 | 2.2bcd | 2.9bcd | 4.7bcd | 2.2 | 3.4ab | 4.3a |
| 77-415 | 2.3bcd | 2.4def | 4.6b-e | 2.3 | 3.1a-d | 3.9ab |
| P-98-1 | 2.3bcd | 2.8b-e | 4.6b-e | 2.3 | 3.6a | 4.2a |
| SPS-23/1 | 2.2bcd | 2.7c-f | 4.5c-f | 2.0 | 3.0a-d | 3.3a-e |
| K-658 | 2.3bcd | 2.4def | 4.2c-f | 2.1 | 2.7b-e | 3.5a-e |
| UCD-6/7 | 2.4bc | 2.6c-f | 4.1c-f | 2.2 | 3.1a-d | 3.9ab |
| 2396-8 | 1.8de | 2.5def | 3.9def | 2.5 | 3.2abc | 4.0a |
| K-940 | 2.2bcd | 2.4def | 3.6ef | 1.8 | 2.4de | 2.9b-e |
| K-841 | 1.9cde | 2.2ef | 3.5f | 1.8 | 2.5cde | 3.3a-e |
| K-90 | 1.8de | 2.0f | 3.5f | 2.3 | 3.1a-d | 3.9ab |
| K-1027 | 1.6e | 2.0f | 3.5f | 2.0 | 2.3de | 3.4a-e |

Means followed by the same letter in a column are not significantly different at $P = 0.05$ by Duncan's Multiple Range Test (SAS Institute 1985).

## TABLE II

## MEAN DAMAGE RATING AND NUMBER OF LEAVES FOR THE ENTRIES IN TEST 2

| | Damage Rating | | | Number of Leaves | | |
|---|---|---|---|---|---|---|
| Entry | Week-1 | Week-2 | Week-3 | Week-1 | Week-2 | Week-3 |
| Toria-A | 2.3 | 4.3a | 5.9a | 1.8 | 2.0 | 2.7c-f |
| UCD-5/1 | 2.2 | 2.7def | 5.3b | 2.4 | 2.7 | 3.1a-d |
| UCD-5 | 2.3 | 2.8c-f | 5.2b | 2.4 | 2.5 | 2.7c-f |
| UCD-6/1 | 2.0 | 2.8c-f | 5.2b | 2.3 | 2.6 | 2.8b-f |
| UCD-5/6 | 2.2 | 2.9c-f | 5.2b | 2.4 | 2.5 | 2.6def |
| UCD-5/9 | 2.1 | 2.7c-f | 5.2b | 2.4 | 2.5 | 3.1a-d |
| UCD-5/5 | 2.1 | 3.3bc | 5.1b | 2.4 | 2.5 | 2.6def |
| UCD-5/8 | 2.2 | 3.4b | 5.1b | 2.3 | 2.7 | 3.2abc |
| UCD-3/6 | 2.1 | 2.5def | 5.1b | 2.1 | 2.4 | 2.5f |
| UCD-4/7 | 2.0 | 2.6def | 5.0bc | 2.3 | 2.4 | 3.4a |
| UCD-5/11 | 2.0 | 2.7c-f | 5.0bc | 2.3 | 3.0 | 3.3ab |
| UCD-5/2 | 2.0 | 2.4ef | 5.0bc | 2.3 | 2.7 | 3.0a-e |
| UCD-4/2 | 2.0 | 2.7def | 5.0bc | 2.2 | 2.7 | 3.1a-d |
| UCD-3/5 | 2.1 | 2.4ef | 4.9bc | 2.1 | 2.4 | 2.5ef |
| UCD-4/4 | 2.0 | 2.3f | 4.9bc | 2.1 | 2.2 | 2.5ef |
| UCD-3/7 | 2.0 | 2.4ef | 4.9bc | 2.3 | 2.6 | 2.8b-f |
| UCD-4/8 | 2.1 | 2.5def | 4.9bc | 2.3 | 2.4 | 3.0a-e |
| UCD-4/1 | 2.1 | 2.5def | 4.9bc | 2.5 | 2.7 | 3.1a-d |
| UCD-5/3 | 2.2 | 3.1bcd | 4.6c | 2.3 | 2.9 | 3.3ab |
| K-841 | 2.2 | 2.7def | 3.4d | 2.2 | 2.6 | 3.1a-d |

Means followed by the same letter in a column are not significantly different at $P = 0.05$ by Duncan's Multiple Range Test (SAS Institute 1985).

## TABLE III

## MEAN DAMAGE RATING AND NUMBER OF LEAVES FOR THE ENTRIES IN TEST 3

| | Damage Rating | | | Number of Leaves | | |
|---|---|---|---|---|---|---|
| Entry | Week-1 | Week-2 | Week-3 | Week-1 | Week-2 | Week-3 |
| 77-1026 | 2.0 | 2.7 | 6.0a | 1.9 | 2.0 | 2.0c |
| Toria-A | 2.7 | 4.2 | 5.9a | 2.0 | 2.0 | 2.0c |
| QH-1 | 2.0 | 3.1 | 5.8ab | 1.8 | 2.0 | 2.0c |
| Sweden-4 | 2.8 | 3.8 | 5.7abc | 2.0 | 2.0 | 2.0c |
| Sweden-6 | 2.4 | 3.4 | 5.7abc | 2.0 | 2.0 | 2.3bc |
| Sweden-3 | 2.9 | 3.9 | 5.7abc | 2.0 | 2.0 | 2.0c |
| Sweden-5 | 2.3 | 3.3 | 5.4a-d | 2.0 | 2.0 | 2.3c |
| 77-1017 | 2.3 | 3.1 | 5.2a-e | 2.0 | 2.0 | 2.0c |
| Sweden-2 | 2.4 | 3.4 | 5.1a-e | 1.8 | 2.0 | 2.0c |
| Sweden-1 | 2.4 | 3.4 | 5.1a-e | 2.0 | 2.0 | 2.0c |
| 77-176 | 2.3 | 3.3 | 5.0a-f | 2.0 | 2.0 | 2.0c |
| QH-2 | 2.5 | 2.9 | 4.8a-g | 2.0 | 2.0 | 2.2c |
| 77-181 | 2.2 | 2.8 | 4.7a-g | 1.9 | 2.0 | 2.2c |
| K-346 | 2.8 | 3.1 | 4.6a-g | 2.0 | 2.1 | 2.4bc |
| K-365 | 2.5 | 3.1 | 4.5b-g | 2.0 | 2.0 | 2.8b |
| K-391 | 2.7 | 3.0 | 4.4c-g | 2.0 | 2.1 | 2.3bc |
| K-145 | 2.4 | 2.8 | 4.3d-g | 2.0 | 2.0 | 2.0c |
| K-393 | 2.1 | 3.1 | 3.8efg | 2.0 | 2.0 | 2.0c |
| 77-242 | 2.0 | 2.1 | 3.6fg | 2.0 | 2.0 | 2.5bc |
| K-841 | 2.4 | 2.4 | 3.4g | 2.0 | 2.1 | 3.4a |

Means followed by the same letter in a column are not significantly different at $P = 0.05$ by Duncan's Multiple Range Test (SAS Institute 1985).

## TABLE IV

## MEAN DAMAGE RATING AND NUMBER OF LEAVES FOR THE ENTRIES IN TEST 4

| | Damage Rating | | | Number of Leaves | | |
|---|---|---|---|---|---|---|
| Entry | Week-1 | Week-2 | Week-3 | Week-1 | Week-2 | Week-3 |
| 77-167 | 2.7bc | 3.7c-g | 6.0a | 2.0 | 2.0 | 2.0c |
| 77-97 | 3.0ab | 4.3bcd | 6.0a | 2.0 | 2.0 | 2.0c |
| 77-1030 | 2.2cd | 5.7a | 6.0a | 2.0 | 2.0 | 2.0c |
| Toria-A | 3.3a | 4.9ab | 5.9a | 2.0 | 2.0 | 2.0c |
| 77-1019 | 2.2cd | 5.1ab | 5.9a | 2.0 | 2.0 | 2.0c |
| 77-1089 | 2.4bcd | 4.1b-e | 5.9a | 2.0 | 2.0 | 2.0c |
| 77-182 | 2.5bcd | 4.0b-f | 5.9a | 2.0 | 2.0 | 2.0c |
| 77-129 | 3.3a | 4.7abc | 5.8a | 1.6 | 2.0 | 2.1c |
| 77-94 | 2.5bcd | 3.7c-g | 5.6a | 2.0 | 2.0 | 2.1c |
| 77-123 | 2.2cd | 2.9fgh | 5.2ab | 2.0 | 2.0 | 2.0c |
| 77-1020 | 2.4cd | 3.3d-h | 5.0ab | 2.0 | 2.0 | 2.0c |
| 77-1008 | 2.5bcd | 2.9fgh | 4.9ab | 2.0 | 2.0 | 2.0c |
| 77-166 | 2.5bcd | 3.2e-h | 4.9ab | 2.0 | 2.0 | 2.0c |
| 77-209 | 2.2cd | 2.7gh | 4.6ab | 2.0 | 2.0 | 2.1c |
| 77-122 | 2.1cd | 2.6gh | 4.2ab | 2.0 | 2.2 | 2.4bc |
| 77-1101 | 2.5cd | 3.3d-h | 4.1ab | 2.0 | 2.0 | 2.1c |
| 77-139 | 2.4bcd | 3.2d-h | 3.9ab | 2.0 | 2.0 | 2.2c |
| K-841 | 2.0d | 2.8gh | 3.3b | 2.0 | 2.2 | 3.1a |
| 77-237 | 2.1cd | 2.4h | 3.3b | 2.0 | 2.0 | 2.4bc |
| K-339 | 2.0d | 2.4h | 3.1b | 2.0 | 2.0 | 2.8ab |

Means followed by the same letter in a column are not significantly different at $P = 0.05$ by Duncan's Multiple Range Test (SAS Institute 1985).

## TABLE V

## MEAN DAMAGE RATING AND NUMBER OF LEAVES FOR THE ENTRIES IN TEST 5

| | Damage Rating | | | Number of Leaves | | |
|---|---|---|---|---|---|---|
| Entry | Week-1 | Week-2 | Week-3 | Week-1 | Week-2 | Week-3 |
| K-1086 | 2.0 | 2.6bcd | 5.9a | 1.9 | 2.0 | 2.0 |
| Toria-A | 2.2 | 4.1a | 5.8a | 2.0 | 2.0 | 2.0 |
| 77-196 | 2.1 | 3.1a-d | 5.4ab | 2.0 | 2.0 | 2.0 |
| 77-92 | 2.2 | 3.7ab | 5.3abc | 2.0 | 2.0 | 2.1 |
| 77-165 | 2.4 | 3.6abc | 5.3a-d | 2.0 | 2.0 | 2.0 |
| 77-96 | 2.0 | 2.7bcd | 4.9a-e | 2.0 | 2.0 | 2.0 |
| 77-150 | 2.1 | 2.9a-d | 4.9a-e | 2.0 | 2.0 | 2.3 |
| 77-117 | 2.0 | 2.4cd | 4.5b-e | 2.0 | 2.0 | 2.3 |
| 77-99 | 2.2 | 2.7bcd | 4.2c-f | 2.0 | 2.0 | 2.2 |
| K-469 | 2.0 | 2.8bcd | 4.2c-f | 2.0 | 2.0 | 2.3 |
| 77-231 | 2.0 | 2.8bcd | 4.1def | 2.0 | 2.0 | 2.5 |
| UCD-13/1 | 2.0 | 2.9bcd | 3.9efg | 2.0 | 2.0 | 2.0 |
| K-910 | 2.2 | 2.5bcd | 3.7efg | 2.0 | 2.0 | 2.6 |
| K-77 | 2.2 | 2.4d | 3.7efg | 2.0 | 2.0 | 2.6 |
| K-345 | 2.0 | 2.5bcd | 3.1gf | 2.0 | 2.0 | 3.0 |
| K-841 | 2.1 | 2.3d | 3.0gf | 2.0 | 2.1 | 3.1 |
| K-760 | 2.0 | 2.1d | 2.9g | 2.0 | 2.1 | 2.9 |
| K-419 | 2.0 | 2.4cd | 2.8g | 2.0 | 2.0 | 2.6 |

Means followed by the same letter in a column are not significantly different at $P = 0.05$ by Duncan's Multiple Range Test (SAS Institute 1985).

## TABLE VI

## MEAN DAMAGE RATING AND NUMBER OF LEAVES FOR THE ENTRIES IN TEST 6

| | Damage Rating | | | Number of Leaves | | |
|---|---|---|---|---|---|---|
| Entry | Week-1 | Week-2 | Week-3 | Week-1 | Week-2 | Week-3 |
| 77-77 | 2.2b-e | 4.2ab | 6.0a | 1.9 | 2.0 | 2.0c |
| Toria-A | 3.3a | 4.9a | 6.0a | 2.0 | 2.0 | 2.0c |
| 77-1018 | 2.2b-e | 5.0a | 6.0a | 2.0 | 2.0 | 2.0c |
| 77-1028 | 2.3bcd | 4.9a | 6.0a | 2.0 | 2.0 | 2.0c |
| 77-90 | 2.5b | 4.0abc | 5.9ab | 2.0 | 2.0 | 2.0c |
| 77-1039 | 2.1de | 3.4bcd | 5.6abc | 2.0 | 2.0 | 2.0c |
| 77-164 | 2.5b | 3.2bcd | 5.5a-d | 2.0 | 2.0 | 2.0c |
| 77-106 | 2.0e | 2.2d | 5.5a-d | 2.0 | 2.0 | 2.0c |
| 77-150 | 2.2b-e | 3.3bcd | 5.1a-e | 2.0 | 2.0 | 2.0c |
| K-93 | 2.1cde | 3.0bcd | 5.1a-e | 2.0 | 2.0 | 2.0c |
| 77-143 | 2.5b | 3.9abc | 5.0b-e | 2.0 | 2.0 | 2.1c |
| 77-178 | 2.2b-e | 3.2bcd | 5.0b-e | 2.0 | 2.0 | 2.0c |
| 77-233 | 2.1de | 3.1bcd | 4.9b-f | 2.0 | 2.0 | 2.0c |
| K-133 | 2.4bc | 3.9abc | 4.8c-f | 2.0 | 2.0 | 2.0c |
| 77-190 | 2.2c-e | 2.3d | 4.7c-f | 2.0 | 2.0 | 2.0c |
| 77-171 | 2.3b-e | 2.4d | 4.6def | 2.0 | 2.0 | 2.1bc |
| 77-268 | 2.1de | 2.7cd | 4.2ef | 2.0 | 2.0 | 2.0c |
| 77-262 | 2.0e | 2.2d | 4.1f | 2.0 | 2.0 | 2.4ab |
| K-186 | 2.0e | 2.5d | 3.2g | 2.0 | 2.1 | 2.6a |
| K-841 | 2.0e | 2.5d | 3.2g | 2.0 | 2.0 | 2.6a |

Means followed by the same letter in a column are not significantly different at *P* = 0.05 by Duncan's Multiple Range Test (SAS Institute 1985).

## TABLE VII

## MEAN DAMAGE RATING AND NUMBER OF LEAVES FOR THE ENTRIES IN TEST 7

| | Damage Rating | | | Number of Leaves | | |
|---|---|---|---|---|---|---|
| Entry | Week-1 | Week-2 | Week-3 | Week-1 | Week-2 | Week-3 |
| Toria-A | 2.8a | 4.8a | 5.7a | 2.0 | 2.0e | 2.2f |
| 77-355 | 2.1c | 3.7bc | 4.7b | 2.0 | 2.7b-e | 3.7b-e |
| UCD-44/5 | 2.0c | 4.0b | 4.7b | 2.0 | 2.4cde | 3.7b-e |
| UCD-166/2 | 2.0c | 3.4bcd | 4.6b | 2.0 | 3.1a-d | 3.8b-e |
| UCD-677 | 2.2c | 3.4bcd | 4.4bc | 2.0 | 2.7b-e | 3.6cde |
| 77-1310 | 2.4b | 3.5bcd | 4.3b-d | 2.0 | 2.1de | 3.6cde |
| UCD-405 | 2.0c | 3.3b-e | 4.3b-d | 2.0 | 3.5ab | 4.8a |
| 77-859 | 2.0c | 3.4bcd | 4.3b-d | 2.0 | 2.9a-d | 3.8b-e |
| 77-934 | 2.0c | 3.1cde | 4.2b-d | 2.0 | 3.1a-d | 4.2a-d |
| UCD-8/2 | 2.1c | 3.1cde | 4.2b-d | 2.0 | 3.6a | 4.2a-d |
| 77-1271 | 2.1c | 3.1cde | 4.2b-d | 2.0 | 2.3cde | 3.9b-e |
| 77-835 | 2.0c | 3.1cde | 4.0b-d | 2.0 | 2.8b-e | 3.6cde |
| 77-1321 | 2.1c | 2.9cde | 3.9b-d | 2.0 | 2.4cde | 3.5de |
| 77-989 | 2.0c | 3.3b-e | 3.9b-d | 2.0 | 3.0a-d | 4.3abc |
| 77-851 | 2.0c | 3.2b-e | 3.9b-d | 2.0 | 3.3abc | 4.5ab |
| UCD-9/7 | 2.0c | 3.2b-e | 3.8b-d | 2.0 | 2.6cde | 3.7b-e |
| UCD-6/15 | 2.0c | 2.9cde | 3.5c-e | 2.0 | 2.6cde | 3.3e |
| UCD-47 | 2.0c | 2.8de | 3.4de | 2.0 | 3.1a-d | 4.1a-d |
| UCD-3 | 2.0c | 2.9cde | 3.3de | 1.9 | 2.5cde | 3.2e |
| K-841 | 2.0c | 2.6e | 2.9e | 2.0 | 3.5ab | 4.5ab |

Means followed by same letter in a column are not significantly different at $P = 0.05$ by Duncan's Multiple Range Test (SAS Institute 1985).

## TABLE VIII

## MEAN DAMAGE RATING NUMBER OF LEAVES FOR THE ENTRIES IN TEST 8

| | Damage Rating | | | Number of Leaves | | |
|---|---|---|---|---|---|---|
| Entry | Week-1 | Week-2 | Week-3 | Week-1 | Week-2 | Week-3 |
| Toria-A | 2.4a | 4.4ab | 5.7a | 2.0 | 2.0 | 2.3f |
| Salam | 2.1bc | 4.5a | 5.2ab | 2.0 | 2.0 | 2.3f |
| R.D.80 | 2.1bc | 3.9abc | 5.1abc | 2.4 | 2.9 | 3.7a-d |
| S-9 | 2.3ab | 4.0abc | 5.1abc | 2.3 | 3.2 | 3.4b-e |
| K-794 | 2.3ab | 4.1ab | 5.0a-d | 2.1 | 2.4 | 4.0abc |
| B.S.A | 2.2abc | 4.3ab | 4.9bcd | 2.0 | 2.5 | 3.7a-d |
| ORI-38-87 | 2.1bc | 4.0abc | 4.8bcd | 2.5 | 3.3 | 4.1ab |
| UCD-390/1 | 2.4a | 3.6b-e | 4.6bcd | 2.4 | 2.9 | 3.7a-d |
| UCD-12/5 | 2.0bc | 3.7a-d | 4.6bcd | 2.1 | 2.7 | 3.6a-e |
| RL-18 | 2.1abc | 3.9abc | 4.6bcd | 2.0 | 2.5 | 3.7a-d |
| ORI-90-87 | 2.2abc | 3.6b-e | 4.5bcd | 2.3 | 3.4 | 4.2a |
| 77-1039 | 2.2abc | 3.9abc | 4.5bcd | 2.1 | 2.6 | 3.2de |
| K-41 | 2.0bc | 3.2c-f | 4.4cd | 2.0 | 2.8 | 3.5a-e |
| ORI-7-87 | 2.1bc | 3.2c-f | 4.3d | 2.0 | 2.5 | 4.2ab |
| K-841 | 2.0c | 2.8ef | 3.4e | 2.1 | 3.1 | 3.7a-d |
| UCD-8/14 | 2.0c | 2.8ef | 3.3e | 2.0 | 2.5 | 3.5a-e |
| UCD-12/3 | 2.0bc | 2.9def | 3.3ef | 2.0 | 2.0 | 2.9ef |
| UCD-3/1 | 2.0c | 2.4f | 3.0ef | 2.0 | 2.3 | 3.2de |
| UCD-8/1 | 2.0c | 2.4f | 2.6f | 2.0 | 2.3 | 3.1de |

Means followed by the same letter in a column are not significantly different at $P = 0.05$ by Duncan's Multiple Range Test (SAS Institute 1985).

# TABLE IX

## MEAN DAMAGE RATING AND NUMBER OF LEAVES FOR THE ENTRIES IN TEST 9

| | Damage Rating | | | Number of Leaves | | |
|---|---|---|---|---|---|---|
| Entry | Week-1 | Week-2 | Week-3 | Week-1 | Week-2 | Week-3 |
| Toria-A | 2.6 | 4.9a | 5.5a | 2.0 | 2.1 | 2.4f |
| UCD-567 | 2.1 | 3.8ab | 5.1ab | 2.0 | 2.2 | 2.7ef |
| UCD-342 | 2.1 | 3.8ab | 5.0abc | 2.1 | 3.1 | 4.3a |
| Altex | 2.0 | 3.6bcd | 4.9abc | 2.0 | 2.4 | 2.9def |
| UCD-467 | 2.1 | 3.8abc | 4.9a-d | 2.0 | 2.1 | 3.1b-e |
| Marnoo | 2.1 | 3.3bcd | 4.7a-e | 2.0 | 2.3 | 3.0c-f |
| PR-269 | 2.1 | 3.3bcd | 4.4b-f | 2.0 | 2.5 | 3.7abc |
| UCD-332 | 2.1 | 3.3bcd | 4.4b-f | 2.2 | 2.4 | 3.7abc |
| UCD-3/10 | 2.0 | 2.9bcd | 4.0c-f | 2.1 | 2.8 | 3.4b-e |
| UCD-61/2 | 2.0 | 2.6bcd | 3.8d-g | 2.0 | 2.2 | 3.2b-e |
| UCD-3/9 | 2.1 | 3.1bcd | 3.8d-g | 2.0 | 2.2 | 3.1b-e |
| UCD-8/4 | 2.0 | 3.1bcd | 3.8efg | 2.0 | 2.6 | 3.5bcd |
| UCD-44/3 | 2.1 | 3.1bcd | 3.8efg | 2.2 | 2.9 | 3.8ab |
| P-61 | 2.0 | 2.8bcd | 3.8efg | 2.0 | 3.1 | 3.5bcd |
| UCD-6/9 | 2.0 | 2.9bcd | 3.6efg | 2.0 | 2.2 | 3.5bcd |
| UCD-29/1 | 2.0 | 2.7bcd | 3.4fg | 2.0 | 2.0 | 3.1c-f |
| K-841 | 2.0 | 2.7bcd | 3.3fg | 2.0 | 2.7 | 3.5bcd |
| UCD-11/12 | 2.0 | 2.4d | 3.2g | 2.0 | 2.2 | 2.9def |
| UCD-13/1 | 2.0 | 2.5cd | 3.1g | 2.0 | 2.6 | 3.0def |
| UCD-11/1 | 2.0 | 2.7bcd | 3.0g | 2.0 | 2.5 | 3.0def |

Means followed by the same letter in a column are not significantly different at $P = 0.05$ by Duncan's Multiple Range Test (SAS Institute 1985).

## TABLE X

## MEAN DAMAGE RATING AND NUMBER OF LEAVES FOR THE ENTRIES IN TEST 10

| | Damage Rating | | | Number of Leaves | | |
|---|---|---|---|---|---|---|
| Entry | Week-1 | Week-2 | Week-3 | Week-1 | Week-2 | Week-3 |
| UCD-45/2 | 2.0c | 3.3bcd | 5.1a | 2.0 | 2.3 | 3.7a |
| Toria-A | 2.2a | 4.5a | 5.0ab | 2.0 | 2.0 | 2.0d |
| Gantyl-5 | 2.1abc | 3.5bc | 4.8abc | 2.0 | 2.1 | 3.0abc |
| UCD-341 | 2.2ab | 3.6ab | 4.5a-d | 2.0 | 2.1 | 3.2abc |
| UCD-333 | 2.0c | 3.0b-e | 4.4a-e | 2.0 | 2.3 | 3.2abc |
| 77-150 | 2.1bc | 2.9b-e | 4.3a-e | 2.0 | 2.9 | 3.9a |
| UCD-405 | 2.0c | 2.7b-e | 4.2a-f | 2.0 | 2.1 | 2.6cd |
| UCD-46/2 | 2.1bc | 2.4de | 4.2a-f | 2.0 | 2.3 | 3.1abc |
| UCD-6/14 | 2.0c | 2.2e | 4.1b-f | 2.0 | 2.2 | 2.7bcd |
| UCD-44/8 | 2.0c | 2.5cde | 4.0c-f | 2.0 | 2.4 | 3.4abc |
| UCD-325 | 2.0c | 3.0b-e | 4.0c-f | 2.1 | 2.5 | 3.5ab |
| UCD-40/2 | 2.1bc | 2.3de | 3.9c-f | 2.0 | 2.2 | 3.7a |
| UCD-6/11 | 2.0c | 2.8b-e | 3.8def | 2.0 | 2.4 | 3.5ab |
| UCD-6/18 | 2.1bc | 3.1b-e | 3.7def | 2.0 | 2.5 | 3.2abc |
| UCD-12/4 | 2.0c | 2.6b-e | 3.7def | 1.9 | 2.1 | 2.8bc |
| UCD-10/8 | 2.0c | 2.3de | 3.6ef | 2.0 | 2.3 | 3.2abc |
| UCD-10 | 2.0c | 2.2de | 3.6ef | 2.0 | 2.3 | 3.2abc |
| UCD-6/23 | 2.1bc | 2.4de | 3.4ef | 2.0 | 2.5 | 3.3abc |
| K-841 | 2.0c | 2.4cde | 3.3f | 2.0 | 2.4 | 3.3abc |

Means followed by the same letter in a column are not significantly different at *P* = 0.05 by Duncan's Multiple Range Test (SAS Institute 1985).

## TABLE XI

## MEAN DAMAGE RATING AND NUMBER OF LEAVES FOR THE ENTRIES IN TEST 11

| | Damage Rating | | | Number of Leaves | | |
|---|---|---|---|---|---|---|
| Entry | Week-1 | Week-2 | Week-3 | Week-1 | Week-2 | Week-3 |
| Toria-A | 3.3a | 5.4 | 6.0a | 2.0a | 2.0 | 2.0 |
| UCD-319 | 2.2bcd | 4.4 | 5.8a | 2.0a | 2.0 | 2.2 |
| UCD-310/4 | 2.3bcd | 4.5 | 5.5ab | 2.0a | 2.0 | 2.5 |
| 2396-6 | 2.0d | 4.5 | 5.4abc | 2.0a | 2.0 | 2.3 |
| UCD-41 | 2.1cd | 4.0 | 5.4abc | 2.0a | 2.0 | 2.5 |
| UCD-635 | 2.1cd | 4.3 | 5.2a-d | 2.0a | 2.0 | 2.3 |
| UCD-303 | 2.4b | 4.0 | 5.2a-d | 2.0a | 2.1 | 2.7 |
| UCD-56/2 | 2.0cd | 3.8 | 5.0a-d | 2.0a | 2.0 | 3.0 |
| UCD-11/5 | 2.1cd | 4.3 | 4.9a-e | 2.0a | 2.0 | 2.7 |
| UCD-7/8 | 2.0d | 3.7 | 4.8a-e | 2.1a | 2.4 | 3.1 |
| UCD-304 | 2.3bcd | 3.6 | 4.8a-e | 2.0a | 2.0 | 2.7 |
| UCD-310/2 | 2.0d | 3.9 | 4.5b-f | 2.0a | 2.0 | 3.0 |
| UCD-6/6A | 2.4bc | 3.7 | 4.4b-f | 2.0a | 2.1 | 3.0 |
| UCD-84 | 2.1cd | 3.5 | 4.0c-g | 2.0a | 2.0 | 3.0 |
| UCD-6/8 | 2.1cd | 3.3 | 3.9d-g | 2.0a | 2.1 | 2.6 |
| UCD-60/5 | 2.0d | 2.7 | 3.6efg | 2.0a | 2.0 | 2.9 |
| K-841 | 2.3bcd | 3.0 | 3.5efg | 2.0a | 2.2 | 3.1 |
| UCD-310/3 | 2.1bcd | 2.4 | 3.2fg | 1.8b | 2.0 | 2.1 |
| UCD-6/13 | 2.1cd | 2.4 | 2.9g | 2.0a | 2.2 | 3.2 |

Means followed by the same letter in a column are not significantly different at $P = 0.05$ by Duncan's Multiple Range Test (SAS Institute 1985).

## TABLE XII

## MEAN DAMAGE RATING AND NUMBER OF LEAVES FOR THE ENTRIES IN TEST 12

| | Damage Rating | | | Number of Leaves | | |
|---|---|---|---|---|---|---|
| Entry | Week-1 | Week-2 | Week-3 | Week-1 | Week-2 | Week-3 |
| Toria-A | 2.7a | 4.4a | 5.4a | 1.8d | 2.0d | 2.1f |
| Malooka | 2.1bc | 3.7b | 5.1a | 1.9cd | 2.0d | 2.7e |
| UCD-675 | 2.1bc | 3.5b | 4.4b | 2.0a-d | 2.4bcd | 3.8ab |
| UCD-8/13 | 2.1bc | 3.3bc | 4.2bc | 2.1abc | 2.7a-d | 3.5b |
| 879-1 | 2.1bc | 2.7c-e | 4.1bc | 1.9cd | 3.1ab | 3.4bcd |
| UCD-166/4 | 2.1bc | 2.8cde | 3.7cd | 2.1a | 3.3a | 4.2a |
| UCD-46/1 | 2.2bc | 2.7bc | 3.7cd | 2.0a-d | 3.1ab | 3.6b |
| UCD-40/1 | 2.1bc | 2.5def | 3.3de | 2.1ab | 2.5bcd | 3.8ab |
| UCD-3/8 | 2.0c | 2.3def | 3.2def | 2.1ab | 3.1ab | 3.8ab |
| UCD-10/11 | 2.1bc | 2.2def | 3.0efg | 2.0a-d | 2.8a-d | 3.4bcd |
| UCD-7/7 | 2.0c | 2.5def | 3.0efg | 2.0a-d | 2.3cd | 3.0cde |
| UCD-42 | 2.3b | 2.8cd | 3.0efg | 2.0a-d | 2.7a-d | 3.5b |
| UCD-10/5 | 2.1bc | 2.4def | 2.7fgh | 2.2a | 2.8abc | 3.8ab |
| UCD-8/6 | 2.1bc | 2.2def | 2.7fgh | 2.1a-d | 2.6a-d | 3.4bc |
| UCD-6/24 | 2.0c | 2.2def | 2.6gh | 2.0a-d | 2.2cd | 3.3bcd |
| UCD-6/26 | 2.0c | 2.3def | 2.6gh | 2.0a-d | 2.6a-d | 3.6b |
| UCD-13/7 | 2.1bc | 2.0f | 2.4gh | 2.0a-d | 2.1cd | 3.6b |
| UCD-3/10 | 2.1bc | 2.2def | 2.4h | 2.0a-d | 2.3cd | 3.5b |
| K-841 | 2.0c | 2.1ef | 2.3h | 1.9bcd | 2.1cd | 2.8de |

Means followed by the same letter in a column are not significantly different at *P* = 0.05 by Duncan's Multiple Range Test (SAS Institute 1985).

## TABLE XIII

## MEAN DAMAGE RATING AND NUMBER OF LEAVES FOR THE ENTRIES IN TEST 13

| | Damage Rating | | | Number of Leaves | | |
|---|---|---|---|---|---|---|
| Entry | Week-1 | Week-2 | Week-3 | Week-1 | Week-2 | Week-3 |
| Toria-A | 2.8a | 4.2a | 5.7a | 1.1c | 2.0 | 2.0 |
| 77-1027 | 2.6ab | 4.3a | 5.7a | 2.0a | 2.0 | 2.0 |
| 77-87 | 2.3c-e | 4.4a | 5.6a | 1.6ab | 2.1 | 2.1 |
| 77-101 | 2.2b-e | 4.0a | 5.6a | 1.3bc | 2.0 | 2.0 |
| 77-89 | 1.9cde | 3.9ab | 5.5ab | 1.4bc | 1.9 | 2.1 |
| UCD-323/2 | 2.5abc | 3.8abc | 5.3abc | 2.0a | 2.0 | 2.5 |
| K-589 | 2.0e | 3.2a-e | 5.0abc | 1.7ab | 2.0 | 2.2 |
| 77-104 | 2.5abc | 3.9ab | 5.0abc | 2.0a | 2.1 | 2.4 |
| UCD-6/10 | 2.5a-d | 3.6a-d | 4.8a-d | 2.0a | 2.0 | 2.4 |
| 77-184 | 2.3b-e | 3.5a-d | 4.7a-e | 2.0a | 2.1 | 2.3 |
| UCD-189 | 2.1de | 2.6de | 4.4a-e | 2.0a | 2.2 | 2.6 |
| UCD-60/7 | 2.3a-e | 3.2a-e | 4.4a-e | 2.0a | 2.0 | 2.2 |
| UCD-87 | 2.1cde | 2.6cde | 4.3a-e | 2.0a | 2.0 | 2.4 |
| UCD-10/6 | 2.0de | 2.8b-e | 4.2b-f | 1.9a | 2.0 | 2.6 |
| UCD-9/3 | 2.0e | 2.6de | 4.1c-f | 1.9a | 2.1 | 2.5 |
| UCD-40/4 | 2.1de | 2.8b-e | 4.0c-f | 2.0a | 2.0 | 2.4 |
| UCD-3/4 | 2.0e | 2.3e | 3.6def | 2.0a | 2.0 | 2.0 |
| UCD-10/4 | 2.0e | 2.6de | 3.4ef | 2.0a | 2.2 | 2.5 |
| K-841 | 2.0e | 2.3e | 2.9f | 1.9a | 2.1 | 2.4 |

Means followed by the same letter in a column are not significantly different at $P = 0.05$ by Duncan's Multiple Range Test (SAS Institute 1985).

## TABLE XIV

## MEAN DAMAGE RATING AND NUMBER OF LEAVES FOR THE ENTRIES IN TEST 14

| | Damage Rating | | | Number of Leaves | | |
|---|---|---|---|---|---|---|
| Entry | Week-1 | Week-2 | Week-3 | Week-1 | Week-2 | Week-3 |
| Toria-A | 3.2a | 4.8a | 5.8a | 1.8 | 2.0f | 2.0e |
| 77-82 | 2.4bc | 4.4ab | 5.4ab | 2.0 | 2.0f | 2.4de |
| 77-84 | 2.3cd | 3.9abc | 5.3abc | 2.0 | 2.3def | 2.8cde |
| 77-107 | 2.5b | 3.4c-f | 5.1a-d | 2.0 | 3.0abc | 4.0ab |
| Gantyl-5 | 2.3bcd | 3.6bcd | 4.8a-e | 2.0 | 2.1ef | 3.4bc |
| K-126 | 2.3bcd | 3.5b-e | 4.3b-f | 2.0 | 2.8a-d | 4.5a |
| R.D.80 | 2.0d | 2.9def | 4.2c-g | 2.0 | 2.9abc | 4.2ab |
| K-1071 | 2.2bcd | 2.8def | 4.0d-g | 2.0 | 2.4c-f | 4.0ab |
| K-269 | 2.0d | 3.0c-f | 4.0d-g | 2.0 | 2.0f | 2.7cde |
| S-9 | 2.0d | 2.9d-f | 3.6e-h | 2.0 | 2.6a-e | 4.2ab |
| K-645 | 2.0d | 2.5f | 3.5fgh | 2.0 | 2.9abc | 4.6a |
| P-61 | 2.1cd | 2.5ef | 3.4fgh | 2.2 | 3.2ab | 4.0ab |
| K-327 | 2.1cd | 2.7def | 3.0gh | 2.0 | 2.6b-e | 4.2ab |
| K-490 | 2.0d | 2.4f | 2.7h | 2.1 | 3.2a | 4.4a |
| K-841 | 2.1cd | 2.4f | 2.6h | 2.0 | 2.1ef | 3.1cd |

Means followed by the same letter in a column are not significantly different at $P = 0.05$ by Duncan's Multiple Range Test (SAS Institute 1985).

## TABLE XV

## FIELD DAMAGE RATING AND GROWTH STAGE OF OILSEED BRASSICAS ENTRIES DURING 1988-89

| Entries | Species | Damage Rating 2 | Growth Stage 2 | Damage Rating 3 | Growth Stage 3 | Damage Rating 4 | Growth Stage 4 |
|---|---|---|---|---|---|---|---|
| UCD-166/2 | B. juncea | 1.0 | 4.0 | 4.7 | 5.0 | 6.0a[1] | 6.0 |
| PR-171-71 | B. juncea | 1.0 | 4.0 | 4.1 | 5.0 | 6.0a | 6.0 |
| UCD-166/2A | B. juncea | 1.0 | 3.9 | 3.8 | 4.9 | 6.0a | 5.9 |
| UCD-10/5 | B. juncea | 1.0 | 4.0 | 3.1 | 5.0 | 6.0a | 6.0 |
| R.D. 80 | B. juncea | 1.0 | 4.0 | 2.9 | 5.0 | 6.0a | 6.0 |
| UCD-6/9 | B. juncea | 1.0 | 4.0 | 2.4 | 5.0 | 6.0a | 6.0 |
| UCD-13/1 | B. juncea | 1.0 | 3.8 | 2.9 | 4.8 | 5.9a | 5.8 |
| SMPI-82 | B. juncea | 1.0 | 4.0 | 3.8 | 5.0 | 5.9a | 6.0 |
| UCD-5 | B. juncea | 1.0 | 4.0 | 2.8 | 5.0 | 5.9a | 6.0 |
| UCD-11/1 | B. juncea | 1.0 | 4.0 | 3.6 | 5.0 | 5.8a | 6.0 |
| UCD-467 | B. juncea | 1.0 | 4.0 | 1.4 | 5.0 | 5.8a | 6.0 |
| UCD-3/4 | B. juncea | 1.0 | 3.5 | 3.5 | 4.5 | 5.7a | 5.5 |
| Porbi raya | B. juncea | 1.0 | 4.0 | 3.4 | 5.0 | 5.7a | 6.0 |
| UCD-5/8 | B. juncea | 1.0 | 4.0 | 2.9 | 5.0 | 5.7a | 6.0 |
| UCD-11/12 | B. juncea | 1.0 | 4.0 | 3.3 | 5.0 | 5.7a | 6.0 |
| UCD-3/9 | B. juncea | 1.0 | 4.0 | 3.1 | 5.0 | 5.7a | 6.0 |
| UCD-60/5 | B. juncea | 1.0 | 3.9 | 2.7 | 4.9 | 5.7a | 5.9 |
| UCD-10/4 | B. juncea | 1.0 | 3.9 | 3.0 | 4.9 | 5.6a | 5.9 |
| UCD-10/8 | B. juncea | 1.0 | 3.9 | 2.4 | 4.9 | 5.6a | 5.9 |
| UCD-6/11 | B. juncea | 1.0 | 4.0 | 2.4 | 5.0 | 5.6a | 6.0 |
| UCD-304 | B. juncea | 1.0 | 3.4 | 2.6 | 4.5 | 5.6a | 5.5 |
| UCD-677 | B. juncea | 1.0 | 3.4 | 1.8 | 4.6 | 5.6a | 5.6 |
| UCD-319 | B. juncea | 1.0 | 3.6 | 2.6 | 4.8 | 5.6a | 5.8 |
| UCD-6/14 | B. juncea | 1.0 | 3.7 | 3.0 | 4.7 | 5.5a | 5.7 |
| UCD-4/7 | B. juncea | 1.0 | 3.0 | 2.3 | 4.3 | 5.5a | 5.3 |
| K-1071 | B. juncea | 1.0 | 3.6 | 1.6 | 4.6 | 5.5a | 5.6 |
| UCD-6/6A | B. juncea | 1.0 | 3.9 | 3.5 | 4.9 | 5.5a | 5.9 |
| UCD-3/6 | B. juncea | 1.0 | 3.4 | 2.1 | 4.7 | 5.5a | 5.7 |
| 855-5 | B. juncea | 1.0 | 1.1 | 1.0 | 2.2 | 5.5a | 3.9 |
| UCD-4/1 | B. juncea | 1.2 | 4.0 | 2.7 | 5.0 | 5.5a | 6.0 |
| UCD-8/1 | B. juncea | 1.0 | 4.0 | 2.1 | 5.0 | 5.4a | 6.0 |
| 77-1103 | B. juncea | 1.0 | 3.1 | 1.5 | 4.3 | 5.4a | 5.3 |
| UCD-6/10 | B. juncea | 1.0 | 4.0 | 2.9 | 5.0 | 5.4a | 6.0 |
| UCD-6/23 | B. juncea | 1.0 | 3.9 | 2.7 | 4.9 | 5.4a | 5.9 |
| UCD-3/9A | B. juncea | 1.0 | 3.9 | 2.2 | 4.9 | 5.4a | 5.9 |

TABLE XV (continued)

| Entries | Species | Damage Rating 2 | Growth Stage 2 | Damage Rating 3 | Growth Stage 3 | Damage Rating 4 | Growth Stage 4 |
|---|---|---|---|---|---|---|---|
| UCD-5/6 | *B. juncea* | 1.0 | 3.8 | 1.6 | 4.9 | 5.4a | 5.9 |
| UCD-3/10 | *B. juncea* | 1.0 | 3.9 | 1.4 | 4.9 | 5.4a | 5.9 |
| UCD-6/24 | *B. juncea* | 1.0 | 4.0 | 3.1 | 5.0 | 5.3a | 6.0 |
| UCD-7/8 | *B. juncea* | 1.0 | 4.0 | 3.0 | 5.0 | 5.3a | 6.0 |
| UCD-3/5 | *B. juncea* | 1.0 | 4.0 | 2.5 | 5.0 | 5.3a | 6.0 |
| UCD-6/18 | *B. juncea* | 1.0 | 3.8 | 2.0 | 4.9 | 5.3a | 5.9 |
| UCD-4/4 | *B. juncea* | 1.0 | 3.8 | 1.9 | 4.8 | 5.3a | 5.8 |
| UCD-341 | *B. juncea* | 1.0 | 3.4 | 1.8 | 4.6 | 5.3a | 5.6 |
| UCD-5/3 | *B. juncea* | 1.0 | 4.0 | 1.7 | 5.0 | 5.3a | 6.0 |
| SM-83001 | *B. juncea* | 1.0 | 4.0 | 2.3 | 5.0 | 5.3a | 6.0 |
| UCD-10/6 | *B. juncea* | 1.0 | 3.5 | 1.7 | 4.5 | 5.3a | 5.5 |
| UCD-323/2 | *B. juncea* | 1.0 | 3.5 | 1.9 | 4.7 | 5.2a | 5.7 |
| UCD-567 | *B. juncea* | 1.0 | 1.9 | 1.9 | 3.4 | 5.2a | 6.0 |
| UCD-5/5 | *B. juncea* | 1.0 | 4.0 | 2.7 | 5.0 | 5.2a | 6.0 |
| UCD-8/14 | *B. juncea* | 1.0 | 4.0 | 2.2 | 5.0 | 5.2a | 6.0 |
| UCD-5/1 | *B. juncea* | 1.0 | 3.5 | 2.0 | 4.6 | 5.2a | 5.6 |
| UCD-5/2 | *B. juncea* | 1.0 | 3.1 | 1.6 | 4.4 | 5.2a | 5.4 |
| UCD-3 | *B. juncea* | 1.0 | 2.8 | 1.5 | 4.1 | 5.2a | 5.1 |
| UCD-5/7 | *B. juncea* | 1.0 | 2.9 | 1.3 | 4.0 | 5.1a | 5.0 |
| ORI-7-87 | *B. juncea* | 1.0 | 2.0 | 1.1 | 4.0 | 5.1a | 5.0 |
| PR-269 | *B. juncea* | 1.0 | 3.0 | 1.0 | 4.2 | 5.1a | 5.2 |
| UCD-8/13 | *B. juncea* | 1.0 | 2.5 | 1.4 | 3.9 | 5.1a | 5.0 |
| UCD-8/4 | *B. juncea* | 1.0 | 3.6 | 1.8 | 4.8 | 5.1a | 5.8 |
| UCD-6/26 | *B. juncea* | 1.0 | 3.8 | 1.6 | 4.9 | 5.1a | 5.9 |
| UCD-5/11 | *B. juncea* | 1.0 | 4.0 | 2.4 | 5.0 | 5.0a | 6.0 |
| UCD-405 | *B. juncea* | 1.0 | 3.7 | 1.6 | 4.7 | 5.0a | 5.7 |
| UCD-3/8 | *B. juncea* | 1.0 | 3.6 | 1.6 | 4.6 | 5.0a | 5.6 |
| UCD-9/7 | *B. juncea* | 1.0 | 3.5 | 1.5 | 4.5 | 5.0a | 5.5 |
| UCD-3/7 | *B. juncea* | 1.0 | 3.4 | 2.8 | 4.4 | 5.0a | 5.4 |
| UCD-675 | *B. juncea* | 1.0 | 3.3 | 2.5 | 4.2 | 5.0a | 5.2 |
| UCD-12/4 | *B. juncea* | 1.0 | 3.8 | 1.7 | 4.8 | 5.0a | 5.8 |
| UCD-6/1 | *B. juncea* | 1.0 | 3.6 | 1.7 | 4.8 | 5.0a | 5.8 |
| UCD-6/13 | *B. juncea* | 1.0 | 3.2 | 1.6 | 4.6 | 5.0a | 5.6 |
| UCD-61/2 | *B. juncea* | 1.0 | 4.0 | 2.7 | 5.0 | 4.9a | 6.0 |
| UCD-7/7 | *B. juncea* | 1.0 | 3.8 | 2.7 | 4.8 | 4.9a | 5.8 |
| UCD-189 | *B. juncea* | 1.0 | 2.7 | 1.8 | 4.2 | 4.9a | 5.2 |
| UCD-8/6 | *B. juncea* | 1.1 | 3.6 | 1.9 | 4.7 | 4.9a | 5.7 |
| UCD-12/3 | *B. juncea* | 1.0 | 3.8 | 1.4 | 4.9 | 4.9a | 5.9 |
| UCD-310/4 | *B. juncea* | 1.0 | 3.4 | 2.7 | 4.5 | 4.8a | 5.6 |

# TABLE XV (continued)

| Entries | Species | Damage Rating 2 | Growth Stage 2 | Damage Rating 3 | Growth Stage 3 | Damage Rating 4 | Growth Stage 4 |
|---|---|---|---|---|---|---|---|
| NARC-82 | *B. napus* | 1.1 | 1.0 | 3.6 | 1.0 | 4.8a | 1.7 |
| UCD-84 | *B. juncea* | 1.0 | 3.6 | 1.8 | 4.7 | 4.8a | 5.7 |
| Tatyoon | *B. napus* | 2.3 | 1.0 | 4.3 | 1.8 | 4.8a | 2.8 |
| UCD-3/1 | *B. juncea* | 1.0 | 3.4 | 1.9 | 4.5 | 4.8a | 5.5 |
| UCD-6/8 | *B. juncea* | 1.0 | 3.5 | 1.4 | 4.5 | 4.8a | 5.5 |
| UCD-342 | *B. juncea* | 1.0 | 3.6 | 1.5 | 4.8 | 4.7a | 5.8 |
| ORI-52-87 | *B. juncea* | 1.0 | 2.5 | 1.4 | 4.0 | 4.6a | 5.0 |
| 77-1039 | *B. juncea* | 1.0 | 2.3 | 1.3 | 3.6 | 4.6a | 4.8 |
| 2396-6 | *B. juncea* | 1.0 | 3.2 | 1.3 | 4.5 | 4.6a | 5.5 |
| K-41 | *B. campestris* | 1.0 | 1.0 | 1.2 | 1.5 | 4.6a | 3.5 |
| K-953 | *B. campestris* | 1.0 | 1.0 | 1.0 | 1.0 | 4.6a | 2.4 |
| Marnoo | *B. napus* | 1.1 | 1.0 | 3.1 | 1.2 | 4.5a | 3.0 |
| BM-1 | *B. juncea* | 1.0 | 1.1 | 1.5 | 4.7 | 4.5a | 5.7 |
| UCD-4/8 | *B. juncea* | 1.0 | 2.9 | 1.8 | 4.1 | 4.4a | 5.1 |
| 77-1110 | *B. juncea* | 1.0 | 2.0 | 1.1 | 4.0 | 4.4a | 5.0 |
| 77-1310 | *B. carinata* | 1.1 | 1.0 | 2.9 | 1.5 | 4.4a | 2.0 |
| P-98-1 | *B. juncea* | 1.0 | 2.3 | 1.0 | 3.8 | 4.4a | 4.9 |
| Ganyou-5 | *B. napus* | 1.2 | 1.0 | 3.0 | 1.0 | 4.3 | 1.6 |
| Salam | *B. napus* | 1.3 | 1.0 | 2.4 | 2.5 | 4.3 | 3.6 |
| UCD-635 | *B. juncea* | 1.0 | 2.5 | 1.8 | 4.0 | 4.3 | 5.0 |
| P-61 | *B. juncea* | 1.0 | 2.8 | 1.6 | 4.2 | 4.3 | 5.2 |
| UCD-6/15 | *B. juncea* | 1.0 | 3.9 | 1.6 | 4.9 | 4.3 | 5.9 |
| UCD-333 | *B. juncea* | 1.0 | 2.3 | 1.6 | 3.6 | 4.3 | 4.7 |
| ORI-6-87 | *B. juncea* | 1.0 | 2.0 | 1.8 | 4.0 | 4.2 | 5.0 |
| UCD-9/3 | *B. juncea* | 1.0 | 3.3 | 1.9 | 4.3 | 4.2 | 5.3 |
| UCD-40/4 | *B. juncea* | 1.0 | 2.1 | 1.0 | 3.3 | 4.1 | 4.6 |
| UCD-442 | *B. juncea* | 1.0 | 2.3 | 1.0 | 3.3 | 4.1 | 4.5 |
| Altex | *B. napus* | 1.0 | 1.0 | 2.9 | 2.5 | 4.1 | 4.0 |
| UCD-44/3 | *B. juncea* | 1.0 | 2.9 | 1.0 | 4.0 | 4.1 | 5.0 |
| UCD-10 | *B. juncea* | 1.0 | 4.0 | 2.3 | 5.0 | 4.0b | 6.0 |
| UCD-325 | *B. juncea* | 1.0 | 2.0 | 1.0 | 4.0 | 4.0b | 5.0 |
| 77-355 | *B. juncea* | 1.0 | 2.4 | 1.0 | 4.0 | 4.0b | 5.0 |
| UCD-40/2 | *B. juncea* | 1.0 | 2.3 | 1.0 | 4.0 | 4.0b | 5.0 |
| UCD-46/1 | *B. juncea* | 1.0 | 2.3 | 1.1 | 4.0 | 3.9b | 5.0 |
| UCD-56/2 | *B. juncea* | 1.0 | 2.0 | 1.0 | 3.5 | 3.9b | 4.6 |
| ORI-61-87 | *B. juncea* | 1.0 | 2.4 | 1.3 | 4.1 | 3.9b | 5.1 |
| 77-934 | *B. juncea* | 1.0 | 2.3 | 1.0 | 3.4 | 3.9b | 4.6 |
| 77-859 | *B. napus* | 1.0 | 2.6 | 1.0 | 4.0 | 3.8b | 5.2 |
| Gantyl-5 | *B. napus* | 1.0 | 1.0 | 2.8 | 1.1 | 3.8b | 2.4 |

TABLE XV (continued)

| Entries | Species | Damage Rating 2 | Growth Stage 2 | Damage Rating 3 | Growth Stage 3 | Damage Rating 4 | Growth Stage 4 |
|---|---|---|---|---|---|---|---|
| UCD-44/5 | B. juncea | 1.0 | 2.3 | 1.8 | 4.0 | 3.8b | 5.0 |
| UCD-5/9 | B. juncea | 1.0 | 3.0 | 1.2 | 4.0 | 3.8b | 5.0 |
| RL-18 | B. juncea | 1.0 | 2.3 | 1.2 | 3.7 | 3.8b | 4.8 |
| UCD-390/1 | B. juncea | 1.0 | 2.1 | 1.2 | 3.7 | 3.8b | 4.8 |
| ORI-81-87 | B. juncea | 1.0 | 1.8 | 1.0 | 3.9 | 3.7b | 4.9 |
| UCD-11/5 | B. juncea | 1.0 | 3.1 | 1.2 | 4.1 | 3.7b | 4.8 |
| K-794 | B. juncea | 1.0 | 1.0 | 1.0 | 1.5 | 3.7b | 3.2 |
| UCD-41 | B. juncea | 1.0 | 2.0 | 1.0 | 3.7 | 3.6b | 4.8 |
| ORI-6-88 | B. juncea | 1.0 | 2.8 | 1.0 | 4.0 | 3.6b | 5.0 |
| UCD-44/8 | B. juncea | 1.0 | 2.1 | 1.4 | 4.0 | 3.6b | 5.0 |
| 77-989 | B. juncea | 1.0 | 2.9 | 1.2 | 3.9 | 3.5b | 4.9 |
| UCD-166/4 | B. juncea | 1.0 | 3.0 | 1.0 | 3.6 | 3.5b | 5.1 |
| ORI-90-87 | B. juncea | 1.0 | 2.1 | 1.1 | 3.6 | 3.5b | 4.7 |
| 77-1321 | B. carinata | 1.0 | 1.0 | 2.1 | 1.0 | 3.5b | 2.0 |
| UCD-13/7 | B. juncea | 1.0 | 2.7 | 1.0 | 3.9 | 3.5b | 4.9 |
| UCD-56 | B. juncea | 1.0 | 1.9 | 1.0 | 3.4 | 3.5b | 4.6 |
| UCD-47 | B. juncea | 1.0 | 3.2 | 1.0 | 4.5 | 3.5b | 5.5 |
| 77-150 | B. juncea | 1.0 | 2.4 | 1.1 | 3.9 | 3.4b | 4.9 |
| ORI-38-87 | B. juncea | 1.0 | 2.5 | 1.5 | 4.0 | 3.4b | 5.0 |
| UCD-45/2 | B. juncea | 1.0 | 2.1 | 1.0 | 3.9 | 3.4b | 4.9 |
| UCD-40/1 | B. juncea | 1.0 | 2.5 | 1.0 | 3.9 | 3.4b | 4.9 |
| UCD-8/2 | B. juncea | 1.0 | 2.3 | 1.0 | 4.0 | 3.4b | 5.0 |
| UCD-303 | B. juncea | 1.0 | 2.3 | 1.0 | 4.0 | 3.4b | 5.0 |
| PR-7 | B. napus | 1.0 | 1.0 | 2.3 | 1.0 | 3.3b | 2.0 |
| UCD-10/11 | B. juncea | 1.0 | 2.2 | 1.1 | 3.6 | 3.3b | 4.7 |
| UCD-166/3 | B. juncea | 1.0 | 2.0 | 1.1 | 2.9 | 3.3b | 4.2 |
| UCD-390/2 | B. juncea | 1.0 | 2.2 | 1.0 | 4.0 | 3.3b | 5.0 |
| UCD-60/7 | B. juncea | 1.0 | 2.0 | 1.0 | 3.6 | 3.3b | 4.7 |
| UCD-46/2 | B. juncea | 1.0 | 2.1 | 1.0 | 3.8 | 3.3b | 4.8 |
| 77-835 | B. juncea | 1.0 | 2.2 | 1.3 | 3.5 | 3.3b | 4.7 |
| S-9 | B. juncea | 1.0 | 2.2 | 1.0 | 3.8 | 3.2b | 4.9 |
| Malkooa | B. napus | 1.0 | 1.0 | 2.8 | 1.1 | 3.2b | 2.2 |
| UCD-42 | B. carinata | 1.0 | 1.8 | 1.4 | 3.2 | 3.2bc | 4.5 |
| 77-1271 | B. carinata | 1.0 | 1.0 | 1.4 | 1.0 | 3.2bc | 2.1 |
| UCD-29/1 | B. carinata | 1.0 | 1.0 | 1.5 | 1.0 | 3.0bc | 2.4 |
| K-963 | B. campestris | 1.0 | 1.0 | 1.0 | 1.6 | 2.9bc | 2.4 |
| 77-851 | B. juncea | 1.0 | 2.4 | 1.0 | 4.0 | 2.8bc | 5.0 |
| UCD-332 | B. juncea | 1.0 | 2.6 | 1.2 | 3.8 | 2.8bc | 4.8 |
| Westar | B. napus | 1.0 | 1.0 | 2.7 | 2.2 | 2.8bc | 4.1 |

TABLE XV (continued)

| Entries | Species | Damage Rating 2 | Growth Stage 2 | Damage Rating 3 | Growth Stage 3 | Damage Rating 4 | Growth Stage 4 |
|---|---|---|---|---|---|---|---|
| ORI-63-87 | B. juncea | 1.0 | 2.1 | 1.0 | 3.5 | 2.8bc | 4.7 |
| 1271-2 | B. napus | 1.0 | 1.1 | 2.5 | 1.5 | 2.7bc | 2.7 |
| 1309-1 | B. carinata | 1.0 | 1.0 | 1.8 | 2.0 | 2.5bc | 2.4 |
| K-841 | E. sativa | 1.0 | 2.1 | 1.0 | 3.1 | 2.4bc | 4.1 |
| B.S.A. | B. campestris | 1.0 | 1.0 | 1.0 | 2.1 | 2.3bc | 3.5 |
| UCD-310/2 | B. juncea | 1.0 | 2.9 | 1.0 | 4.4 | 2.3bc | 5.4 |
| K-967 | E. sativa | 1.0 | 2.8 | 1.1 | 3.9 | 2.2bc | 4.9 |
| UCD-12/5 | B. juncea | 1.0 | 1.9 | 1.1 | 2.8 | 1.9bc | 3.6 |
| UCD-310/3 | B. carinata | 1.0 | 1.0 | 1.1 | 1.0 | 1.7bc | 1.7 |
| UCD-87 | B. juncea | 1.0 | 1.9 | 1.0 | 3.0 | 1.7bc | 4.5 |
| UCD-442/5 | B. juncea | 1.0 | 1.8 | 1.0 | 2.5 | 1.7bc | 4.1 |
| K-706 | E. sativa | 1.0 | 1.7 | 1.0 | 3.0 | 1.6bc | 4.3 |
| K-427 | E. sativa | 1.0 | 2.0 | 1.0 | 3.8 | 1.4bc | 4.9 |
| 3161-3 | E. sativa | 1.0 | 2.0 | 1.0 | 3.0 | 1.3bc | 4.2 |

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[1] Means followed by "a" were not different from the most susceptible entry; "b" were not different from K-841; and "c" were not different from best entry by "t-test" $P=0.05$ (SAS Institute 1985).

## TABLE XVI

## MEAN DAMAGE RATING OF ENTRIES TESTED IN SINGLE REPLICATE AGAINST TURNIP APHID POPULATION FROM LANE, OKLAHOMA

| Entry | Species | Damage Rating | | |
|---|---|---|---|---|
| | | First Week | Second Week | Third Week |
| Toria-A (Flat 1) | *B. campestris* | 5.4±0.54 | 6.0±0 | 6.0±0 |
| Toria-A (Flat 2) | *B. campestris* | 5.8±0.44 | 6.0±0 | 6.0±0 |
| Toria-A (Flat 3) | *B. campestris* | 5.6±0.89 | 6.0±0 | 6.0±0 |
| Laxmi | *B. campestris* | 3.8±0.83 | 6.0±0 | 6.0±0 |
| K-47 | *B. campestris* | 2.6±0.50 | 6.0±0 | 6.0±0 |
| K-145 | *B. campestris* | 2.4±0.54 | 6.0±0 | 6.0±0 |
| K-365 | *B. campestris* | 2.8±0.45 | 5.8±0.45 | 6.0±0 |
| UCD-10 | *B. juncea* | 2.2±0.45 | 5.6±0.54 | 6.0±0 |
| UCD-166/4 | *B. juncea* | 5.6±0.54 | 6.0±0 | 6.0±0 |
| SPS-23/1 | *B. juncea* | 3.8±0.45 | 6.0±0 | 6.0±0 |
| 77-1321 | *B. carinata* | 2.2±0.45 | 4.8±0.45 | 6.0±0 |
| 77-989 | *B. carinata* | 3.2±0.45 | 6.0±0 | 6.0±0 |
| UCD-40/1 | *B. juncea* | 2.4±0.54 | 5.2±0.44 | 6.0±0 |
| 77-209 | *B. carinata* | 4.2±0.96 | 6.0±0 | 6.0±0 |
| UCD-6/18 | *B. juncea* | 2.8±0.45 | 5.8±0.45 | 6.0±0 |
| UCD-6/24 | *B. juncea* | 2.2±0.45 | 4.6±0.50 | 6.0±0 |
| UCD-60/5 | *B. juncea* | 3.8±0.45 | 6.0±0 | 6.0±0 |
| UCD-6/9 | *B. juncea* | 2.2±0.45 | 5.8±0.45 | 6.0±0 |
| UCD-3 | *B. juncea* | 3.0±0.71 | 5.2±1.10 | 5.8±0.45 |
| UCD-8/6 | *B. juncea* | 2.0±0 | 5.4±0.89 | 5.8+0.40 |
| 77-237 | *B. campestris* | 2.4±0.55 | 4.0±0 | 5.8±0.45 |
| UCD-11/12 | *B. juncea* | 2.2±0.44 | 4.8±1.1 | 5.8±0.45 |
| UCD-42 | *B. juncea* | 1.8±0.45 | 5.0±1.0 | 5.8±0.45 |
| UCD-7/7 | *B. juncea* | 2.2±0.45 | 5.6±0.55 | 5.8±0.45 |
| S-9 | *B. juncea* | 2.2±0.45 | 4.4±0.54 | 5.6±0.89 |
| UCD-61/2 | *B. juncea* | 3.2±0.45 | 5.2±1.1 | 5.6±0.89 |
| UCD-3/1 | *B. juncea* | 2.0±0 | 5.0±1.0 | 5.6±0.55 |
| UCD-8/4 | *B. juncea* | 2.6±0.54 | 4.8+1.1 | 5.4±0.54 |
| UCD-10/8 | *B. juncea* | 2.4±0.55 | 5.0±1.22 | 5.2±1.30 |
| UCD-6/5 | *B. juncea* | 2.4±0.55 | 4.4±0.54 | 5.0±1.00 |
| 77-1271 | *B. carinata* | 2.4±0.54 | 3.2±0.45 | 4.8±1.10 |
| UCD-6/26 | *B. juncea* | 2.3±0.57 | 4.0±1.79 | 4.7±1.10 |

TABLE XVI (continued)

| Entry | Species | Damage Rating | | |
|---|---|---|---|---|
| | | First Week | Second Week | Third Week |
| UCD-6/13 | B. juncea | 2.0±0 | 4.0±0 | 4.7±0.95 |
| UCD-44/3 | B. juncea | 2.0±0 | 3.0±0 | 4.6±0.89 |
| UCD-6/23 | B. juncea | 2.0±0 | 4.0±0 | 4.6±0.89 |
| 77-835 | B. carinata | 2.2±0.45 | 3.4±0.54 | 4.2±0.45 |
| UCD-6/11 | B. juncea | 2.0±0 | 3.6±1.81 | 4.0±1.87 |
| UCD-29/1 | B. carinata | 3.2±1.89 | 3.7±1.70 | 4.0±1.00 |
| K-645 | B. campestris | 2.8±0.83 | 3.4±0.89 | 4.0±1.20 |
| P-61 | B. juncea | 2.2±0.45 | 3.6±1.34 | 3.6±0.55 |
| UCD-10/5 | B. juncea | 2.4±0.54 | 2.8±0.83 | 3.6±1.50 |
| UCD-13/1 | B. juncea | 2.0±0 | 3.4±0.84 | 3.6±0.89 |
| UCD-13/7 | B. juncea | 2.2±0.45 | 3.0±0 | 3.6±0.54 |
| UCD-310/3 | B. carinata | 2.0±0 | 3.0±0 | 3.6±0.55 |
| UCD-10/15 | B. juncea | 2.4±0.54 | 3.2±1.10 | 3.4±0.89 |
| UCD-46/1 | B. juncea | 2.2±0.44 | 2.8±0.45 | 3.2±0.45 |
| UCD-12/4 | B. juncea | 2.2±0.45 | 3.0±0 | 3.2±0.45 |
| UCD-9/7 | B. juncea | 2.0±0 | 2.6±0.54 | 3.0±1.00 |
| UCD-8/14 | B. juncea | 2.0±0 | 2.2±0.45 | 2.4±0.55 |
| UCD-8/1 | B. juncea | 2.0±0 | 2.0±0 | 2.4±0.54 |
| K-841 | E. sativa | 2.0±0.89 | 2.0±0 | 2.2±0.45 |
| UCD-11/1 | B. juncea | 2.0±0 | 2.0±0 | 2.0±0 |
| UCD-3/9 | B. juncea | 2.0±0 | 2.0±0 | 2.0±0 |

## TABLE XVII

## APHIDS/ENTRY AND MEAN DAMAGE RATING OF ENTRIES IN LATIN SQUARE DESIGN TEST 1

|  | Aphids/Entry After Hour Infestation |  |  | Damage Rating After Week Infestation |  |  |
|---|---|---|---|---|---|---|
| Entry | Species | 8 h | 24 h | First Week | Second Week | Third Week |
| Toria-A | *B. campestris* | 100[1] | 100[1] | 2.9a | 5.4a | 6.0a |
| 77-1321 | *B. carinata* | 136 | 63 | 1.9bc | 2.3bc | 3.3b |
| UCD-9/7 | *B. juncea* | 100 | 68 | 1.9bc | 2.0cd | 2.8c |
| K-841 | *E. sativa* | 71 | 32 | 2.1b | 2.1cd | 2.7cd |
| UCD-46/1 | *B. juncea* | 100 | 89 | 2.1b | 2.5b | 2.7cd |
| UCD-3 | *B. juncea* | 142 | 100 | 2.0bc | 2.0cd | 2.5cde |
| UCD-8/1 | *B. juncea* | 93 | 42 | 1.8c | 1.8d | 2.3de |
| UCD-11/12 | *B. juncea* | 86 | 74 | 1.9bc | 1.9cd | 2.2de |
| UCD-3/9 | *B. juncea* | 93 | 68 | 1.9bc | 1.9cd | 2.1de |
| UCD-60/5 | *B. juncea* | 71 | 63 | 1.9bc | 2.0cd | 2.2de |
| UCD-8/14 | *B. juncea* | 68 | 93 | 1.9bc | 1.8d | 2.0e |

Means followed by the same letter in a column are not significantly different at $P = 0.05$ by Duncan's Multiple Range Test (SAS Institute 1985).

[1] Other counts adjusted to percentage of Toria-A.

## TABLE XVIII

## APHIDS PER ENTRY AND MEAN DAMAGE RATING OF ENTRIES IN LATIN SQUARE DESIGN TEST 2

| | | Aphids/Entry After Hour Infestation | | Damage Rating After Week Infestation | | |
|---|---|---|---|---|---|---|
| Entry | Species | 8 h | 24 h | First Week | Second Week | Third Week |
| Toria-A | *B. campestris* | 64cde | 79ab | 2.5ab | 4.5a | 5.5a |
| UCD-44/3 | *B. juncea* | 70bcde | 75b | 2.7a | 3.9ab | 5.1a |
| UCD-13/7 | *B. juncea* | 96a | 93ab | 2.3bc | 3.8b | 5.3a |
| UCD-10/15 | *B. juncea* | 82abcd | 84ab | 2.5ab | 3.4bc | 5.0a |
| 77-1271 | *B. carinata* | 92ab | 105a | 2.2bc | 2.9cd | 3.8bc |
| UCD-12/4 | *B. juncea* | 69bcde | 70bc | 2.0c | 2.4de | 3.0de |
| UCD-310/3 | *B. carinata* | 78abcd | 88ab | 2.2bc | 2.4de | 3.1cd |
| K-841 | *E. sativa* | 47e | 44c | 2.1bc | 2.3de | 3.0de |
| UCD-6/23 | *B. juncea* | 57de | 79ab | 2.0c | 2.1e | 2.9de |
| UCD-13/1 | *B. juncea* | 85abc | 72bc | 1.9c | 2.1e | 2.2e |
| UCD-6/24 | *B. juncea* | 73bcde | 76bc | 1.9c | 2.0e | 2.9de |

Means followed by the same letter in a column are not significantly different at $P = 0.05$ by Duncan's Multiple Range Test (SAS Institute 1985).

## TABLE XIX

## MEAN DEVELOPMENT TIME, REPRODUCTION, PERCENT SURVIVAL, INTRINSIC RATE OF INCREASE AND ADJUSTED INTRINSIC RATE OF INCREASE OF TURNIP APHID ON DIFFERENT OILSEED BRASSICA ENTRIES

| Entries | Development Time (d) | Reproduction in (md) | Percent Survival | Intrinsic Rate of Increase(rm) | Adjusted (rm) |
|---|---|---|---|---|---|
| Toria-A | 7.9e | 47a | 95a | 0.364a | 0.360a |
| UCD-42 | 8.7cde | 23b | 94ab | 0.262bc | 0.256b |
| UCD-44/3 | 8.9cd | 20bc | 89abc | 0.256bc | 0.248b |
| UCD-13/1 | 8.6cde | 24b | 85abc | 0.276bc | 0.261b |
| UCD-13/7 | 8.2de | 21bc | 84abcd | 0.278bc | 0.264b |
| UCD-11/12 | 8.1de | 25b | 76abcd | 0.289b | 0.266b |
| UCD-6/24 | 9.3abc | 22b | 74abcd | 0.247bc | 0.224b |
| UCD-29/1 | 8.0e | 23b | 70abcd | 0.284b | 0.244b |
| UCD-6/13 | 8.9bcd | 26b | 68cd | 0.269bc | 0.242b |
| UCD-12/4 | 9.1abc | 21bc | 57d | 0.234cd | 0.183c |
| UCD-310/3 | 9.7a | 15cd | 70bcd | 0.204de | 0.178c |
| K-841 | 9.7ab | 13d | 69bcd | 0.191e | 0.162c |

Means followed by the same letter in a column are not significantly different at *P* = 0.05 DMRT (SAS Institute 1985)

## TABLE XX

## PREDICTED AND ACTUAL APHID COUNTS AND DAMAGE RATING AT DIFFERENT TIME INTERVALS ON TORIA-A, UCD-13/1, UCD-310/3 AND K-841 FROM AN INFESTATION OF 20 APHIDS

| Days | Entry | Predicted Count | Actual Count | Damage Rating |
|---|---|---|---|---|
| 5 | Toria-A | 94 | 112a | 1.9a |
| 5 | UCD-13/1 | 66 | 41b | 1.0b |
| 5 | UCD-310/3 | 48 | 44b | 1.0b |
| 5 | K-841 | 45 | 19c | 1.1b |
| 10 | Toria-A | 439 | 470a | 2.9a |
| 10 | UCD-13/1 | 216 | 320b | 1.8c |
| 10 | UCD-310/3 | 115 | 87c | 2.1b |
| 10 | K-841 | 102 | 68c | 1.7c |
| 12 | Toria-A | 815 | 972 | 3.2 |
| 15 | Toria-A | 1052 | 654 | 5.3a |
| 15 | UCD-13/1 | 709 | 931 | 2.0c |
| 15 | UCD-310/3 | 275 | 707 | 2.4b |
| 15 | K-841 | 229 | 283 | 2.2bc |
| 17 | Toria-A | --- | 159 | 5.8 |
| 18 | UCD-13/1 | 1446 | 1264 | 2.9 |
| 18 | UCD-310/3 | 465 | 1069 | 3.0 |
| 20 | Toria-A | --- | --- | 6.0a |
| 20 | UCD-13/1 | 1317 | 1123 | 3.2b |
| 20 | UCD-310/3 | 660 | 787 | 3.3b |
| 20 | K-841 | 516 | 480 | 2.5c |
| 23 | UCD-13/1 | --- | 851 | 5.1 |
| 23 | UCD-310/3 | 1114 | 728 | 4.6 |
| 23 | K-841 | 840 | 861 | 3.1 |
| 26 | UCD-310/3 | --- | 595 | 4.6 |
| 26 | UCD-13/1 | --- | 117 | 6.0 |
| 26 | K-841 | 1369 | 1244 | 3.4 |
| 31 | UCD-310/3 | --- | 171 | 4.6 |
| 31 | K-841 | --- | 1050 | 3.7 |
| 36 | UCD-310/3 | --- | --- | 5.1 |
| 36 | K-841 | --- | 599 | 4.4 |

Means followed by the same letter, on the same day, are not significantly different at $P = 0.05$ by Duncan's Multiple Range Test (SAS Institute 1985).

## TABLE XXI

## MEAN FREQUENCIES OF FEEDING BEHAVIOR OBSERVED IN 480 MINUTES OF TURNIP APHIDS ON SIX OILSEED BRASSICA ENTRIES TEST 1

| Entry | Baseline | Probes | Salivation | Nonphloem ingestion[1] | X-wave single[1] | X-wave multiple[1] | Phloem ingestion[1] |
|---|---|---|---|---|---|---|---|
| UCD-13/1 | 16.0 | 16.0 | 15.0ab | 4.6 | 1.5 | 4.2ab | 4.0abc |
| UCD-13/7 | 34.7 | 34.5 | 21.7a | 4.8 | - | 5.0ab | 5.0abc |
| UCD-6/13 | 29.7 | 29.7 | 15.2ab | 2.0 | 1.0 | 3.8ab | 3.2bc |
| UCD-6/24 | 27.7 | 27.3 | 20.8a | 1.5 | 1.0 | 7.3a | 7.3a |
| K-841 | 26.8 | 26.8 | 20.5a | 2.2 | 2.7 | 4.2ab | 6.2ab |
| Toria-A | 18.3 | 18.3 | 10.3b | 4.0 | - | 1.8b | 1.3c |

[1] Not all aphids displayed this behavior; frequencies are means of only those which did.

Means followed by the same letter in column are not significantly different at $P = 0.05$ by Duncan's Multiple Range Test (SAS Institute 1985).

## TABLE XXII

## MEAN FREQUENCIES OF FEEDING BEHAVIOR OF TURNIP APHID OBSERVED IN 470 MINUTES ON SIX OILSEED BRASSICA ENTRIES TEST 2

| Entry | Baseline | Probes | Salivation | Nonphoem ingestion[1] | X-wave single[1] | X-wave multiple[1] | Phloem ingestion[1] |
|---|---|---|---|---|---|---|---|
| UCD-11/12 | 25.8 | 25.7 | 18.3 | 3.7 | 3.0 | 5.8 | 7.2 |
| UCD-12/4 | 25.8 | 25.7 | 17.2 | 1.0 | 2.0 | 3.5 | 4.5 |
| UCD-29/1 | 15.7 | 15.7 | 16.0 | 1.8 | 2.0 | 4.0 | 5.0 |
| UCD-310/3 | 25.7 | 25.2 | 16.8 | 2.8 | - | 3.8 | 3.8 |
| UCD-42 | 32.7 | 32.7 | 21.5 | 2.2 | 2.0 | 4.8 | 5.2 |
| UCD-44/3 | 17.2 | 17.0 | 14.2 | 3.3 | 1.2 | 4.2 | 5.0 |

---

[1] Not all aphids displayed this behavior; frequencies are means of only those which did.

## TABLE XXIII

## MEAN DURATION (MINUTES) OF FEEDING BEHAVIOR OBSERVED IN 480 MINUTES FOR TURNIP APHIDS ON SIX OILSEED BRASSICA ENTRIES TEST 1

| Entry | Baseline | Probes | Salivation | Nonphloem ingestion[1] | X-wave single[1] | X-wave multiple[1] | Phloem ingestion[1] |
|---|---|---|---|---|---|---|---|
| UCD-13/1 | 4.9 | 1.0 | 13.7 | 31.5 | 1.0 | 3.0b | 48.4b |
| UCD-13/7 | 4.3 | 0.9 | 8.8 | 27.5 | - | 4.1b | 9.0b |
| UCD-6/13 | 4.5 | 0.9 | 11.6 | 27.8 | 1.0 | 3.3b | 34.3b |
| UCD-6/24 | 2.7 | 0.9 | 10.2 | 25.4 | 1.0 | 2.0b | 18.4b |
| K-841 | 3.6 | 1.0 | 13.0 | 24.9 | 1.0 | 1.3b | 22.7b |
| Toria-A | 2.4 | 0.7 | 13.2 | 26.3 | - | 26.8a | 207.3a |

[1] Not all aphids displayed this behavior, but value given assumed 6 potential sets of possibilities.

Means followed by the same latter in column are not significantly different at $P = 0.05$ by Duncans Multiple Range Test (SAS Institute 1985).

## TABLE XXIV

## MEAN DURATION (MINUTES) OF FEEDING BEHAVIOR OBSERVED IN 470 MINUTES OF TURNIP APHIDS ON SIX OILSEED BRASSICAS ENTRIES IN TEST 2

| Entry | Baseline | Probes | Salivation | Nonphloem ingestion[1] | X-wave single[1] | X-wave multiple[1] | Phloem ingestion[1] |
|---|---|---|---|---|---|---|---|
| UCD-11/12 | 4.9 | 0.9 | 9.1 | 33.0 | 1.0 | 2.1 | 15.6 |
| UCD-12/4 | 4.6 | 0.9 | 10.3 | 2.1 | 0.8 | 1.9 | 56.1 |
| UCD-29/1 | 3.1 | 0.8 | 10.9 | 36.8 | 0.7 | 5.8 | 40.0 |
| UCD-310/3 | 3.6 | 0.8 | 10.6 | 41.3 | - | 2.0 | 25.7 |
| UCD-42 | 3.1 | 0.8 | 10.2 | 30.9 | 1.1 | 2.4 | 19.4 |
| UCD-44/3 | 3.4 | 0.9 | 11.3 | 21.0 | 0.8 | 2.6 | 56.9 |

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[1] Not all aphids displayed this behavior; but value given assumed 6 potential sets of possibilities.

## TABLE XXV

## TOTAL DURATION (MINUTES) OF FEEDING BEHAVIOR OBSERVED IN 480 MINUTES OF TURNIP APHIDS ON SIX OILSEED BRASSICA ENTRIES IN TEST 1

| Entry | Baseline | Probes | Salivation | Nonphloem ingestion[1] | X-wave single[1] | X-wave multiple[1] | Phloem ingestion[1] |
|---|---|---|---|---|---|---|---|
| UCD-13/1 | 51.0 | 15.2 | 146.9bc | 111.0 | 0.5 | 7.4b | 148.0ab |
| UCD-13/7 | 126.9 | 33.0 | 184.1ab | 89.7 | - | 12.9b | 34.0b |
| UCD-6/13 | 134.8 | 28.2 | 178.0ab | 53.9 | 0.2 | 7.8b | 77.0ab |
| UCD-6/24 | 84.6 | 24.9 | 202.7ab | 29.7 | 0.3 | 16.4b | 121.3ab |
| K-841 | 83.6 | 23.8 | 248.4a | 46.1 | 1.3 | 3.7b | 73.0ab |
| Toria-A | 39.4 | 13.4 | 92.6c | 34.9 | - | 47.6a | 252.0a |

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[1] Not all aphids displayed this behavior, but value given assumed 6 potential sets of possibilities.

Means followed by the same latter in column are not significantly different at *P* = 0.05 by Duncans Multiple Range Test (SAS Institute 1985).

## TABLE XXVI

## TOTAL DURATION (MINUTES) OF FEEDING BEHAVIOR OBSERVED IN 470 MINUTES FOR TURNIP APHIDS ON SIX OILSEED BRASSICA ENTRIES IN TEST 2

| Entry | Baseline | Probes | Salivation | Nonphloem ingestion[1] | X-wave single[1] | X-wave multiple[1] | Phloem ingestion[1] |
|---|---|---|---|---|---|---|---|
| UCD-11/12 | 127.3 | 24.0 | 170.0 | 57.4 | 1.2 | 8.0 | 82.0 |
| UCD-12/4 | 119.2 | 24.7 | 160.8 | 0.7 | 0.8 | 6.6 | 157.2 |
| UCD-29/1 | 50.7 | 13.7 | 179.1 | 44.5 | 0.7 | 30.5 | 150.8 |
| UCD-310/3 | 106.8 | 20.0 | 164.3 | 87.3 | - | 6.8 | 84.5 |
| UCD-42 | 102.0 | 26.0 | 200.3 | 65.4 | 0.2 | 11.3 | 64.7 |
| UCD-44/3 | 55.3 | 14.7 | 161.2 | 35.5 | 0.7 | 12.3 | 190.3 |

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[1] Not all aphids displayed this behavior, but value given assumed 6 potential sets of possibilities.

# VITA

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