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May 21/03

Management of lygus bugs and cabbage seedpod weevils in canola

Final report for CARP AG#2001-00-11

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ABSTRACT

Lygus bugs and cabbage seedpod weevils are serious insect pests of canola in southern Alberta. In 2000 and 2001 a plot insecticide trial was conducted to develop a chemical management strategy for the two pests. Results from the study showed that a single application at the early pod stage was as effective as multiple applications to protect yields and control of lygus bugs was not adequate with single applications at the bud stage. During both years, canola crop development was delayed because of drought and flea beetle pressure and caused plants to escape damage from cabbage seedpod weevil. Insecticide application had little impact on cabbage seedpod weevil infestation levels and the results indicate that late-planted fields should not be sprayed for weevils. Observations from commercial fields and other ongoing plot trials confirmed that only early-seeded canola field may need spraying against weevils. A second study was designed to determine impact of a range of lygus and weevil densities on canola yield. Results were available only for the 2000 growing season and plants were impacted by drought stress. The study suggested that substantial seed yield can be loss when densities of lygus and weevils reach 2 of each pest per plant. Further research on weevil-canola plant interactions and studies on sweeping efficiency are required to confirm these results and develop economic thresholds.

BACKGROUND

Lygus research in the Canadian prairies dates back to the 1930's. Salt (1945) conducted a survey in 1938 and determined that lygus bugs in southern Alberta have two generations per year; similar findings were reported more recently in southern Manitoba by Gerber and Wise (1995). In northern areas of the Prairie Provinces there is only one generation per year (Butts and Lamb 1991a, Craig 1983). This variation in seasonal activity results in greater accumulation of lygus bugs in earlier planted canola in the north (Butts and Lamb 1991a) but fewer in the southern regions (Leferink and Gerber 1997). Regardless of total number of generations in a region, lygus only complete one generation in canola and can be controlled with a single spray at the early pod stage (Butts and Lamb 1991b, Wise and Lamb 1998b).

The potential pest status of lygus bugs in canola was first recognised by Butts and Lamb (1990a,b, 1991a,b) in the early 1980's. Their research characterised the damage caused by lygus and quantified the potential losses attributed to lygus bugs. More recent, Wise and Lamb (1998a,b) developed sampling protocols and economic thresholds for lygus bugs in southern Manitoba. Recent outbreaks of Lygus species in various parts of Alberta and Northern Saskatchewan have prompted additional research to quantify damage caused at the earlier growth stages of canola. Current work by Jones (Alberta Agriculture) and Butts, Cárcamo and Otani (Agriculture and Agri-Food Canada) being carried out in Beaverlodge, Edmonton and Lethbridge, will determine the potential for canola compensation to lygus herbivory during the bud to flower growth stages.

There are no references in the scientific literature to cabbage seedpod weevil damage to canola in Canada, although the insect has been in B.C. for over 60 years (Baker 1936). Dolinski (1979) reviewed the biology and management of the weevil in Europe where the weevil is native.

Economic thresholds in Europe range from 0.25 weevils per plant in Finland (Tulisalo 1976) to 1-2 weevils per plant in other countries (see references in Dolinski 1979). In the Pacific Northwest of the U.S. the weevil can cause losses of up to 35 % of yield if not controlled. There is no data on economic thresholds but spraying has been recommended if there are 3-6 weevils per sweep (McAffrey et al. 1986) or even 1-2 weevils per sweep (Harmon, pers. comm.). Spraying with a pyrethroid at full bloom is recommended to target ovipositing adults rather than at the pod stage when larvae are protected inside seeds (Bragg and Burns1999).

Economic thresholds for lygus control are available for early and mid-pod stages of canola and current research is assessing potential damage at earlier growth stages. Despite the long history of economic losses by cabbage seedpod weevil in the Pacific Northwest, there are still no firm economic thresholds to make control decisions. However, current research in Alberta is assessing weevil damage and spray trials in progress should provide thresholds to target this pest. These approaches focus on individual pests, however, during non-outbreak years of either pest or in locations where the pests occur at endemic levels, the combined damage may cause economic losses that would not be predicted from individual abundances of each pest species. Therefore, there is a need to develop economic thresholds for the combined damage of these two pests.

OBJECTIVES:

1) To determine the timing and frequency of insecticide application to maximize canola yields in relation to lygus and cabbage seedpod weevil pressures. These two insect pests have different critical activity periods in canola in southern Alberta, therefore it is crucial to determine if a

single application at early flower is sufficient to control both pests or if additional applications are needed at the end of flowering for lygus bugs.

2) To determine canola yield losses caused by a range of combinations of lygus bugs and cabbage seedpod weevils at densities below and above their recommended individual economic thresholds. Both pests attack the same reproductive canola structures, buds, flowers and developing seeds. Canola may not be able to compensate for combined low levels of herbivory at densities that currently do not call for control actions.

EXPERIMENTAL METHODS

Study site and agronomic activities

A plot insecticide trial and a cage study were conducted simultaneously in 2000 and 2001 to address objectives 1 and 2, respectively. The study site was located 2 km east of the Lethbridge Research Centre on land rented from Victory Church (GPS coordinates: 49°42'N 112°44'W). Prior to the 2000 growing season, the land was kept in chemical fallow and had a winter cover of oats to prevent soil erosion. Soil samples collected and analyzed in the fall of 1999 revealed adequate levels of all macronutrients including sulphur, therefore, no additional fertilizer was added.

On May 2nd, 2000 the land was disced to prepare the seedbed and Edge was incorporated as pre-plant weed control. On the same day, Q2 canola (untreated seed, except for fungicide) was planted using a John Deer pan drill at the rate of 6 lb/acre, 6 inch row spacing and at half an inch depth. Moisture conditions at seeding were poor and patchy germination was observed around May 15th. Drought conditions persisted throughout southern Alberta with hardly any rain in

June and early July. Therefore, to salvage the insecticide timing experiments, 3 inches of water were added between July 13th (2 inches) and July 17th (1 inch).

Flea beetle pressure at the site was extremely high and cotyledon consumption was estimated to be over 50 % in some plots, therefore, Decis at 60 ml/ac was sprayed on May 23rd. Drought conditions throughout the seedling stage, plus flea beetle pressure, created a patchy stand (range of 25 to 55 plants/ sq m) and variable growth stages (as of July 19: 10 % bud, 45 % early flower and 45 % mid to late flower). Cabbage seedpod weevils (1-2 per plant) were observed resting on many canola seedlings (pre-bud stage) around the first week of June and lygus bugs were also numerous at the flower and pod stages in late July.

The land used for the 2001 studies was at the same location and it was kept under chemical summer fallow and winter cereal cover in 2000 but had been cropped to canola in 1999. On April 27th, the land was disced to prepare the seedbed and Edge was incorporated as pre-plant weed control. Fertilizer was incorporated as per recommended rates after soil analysis. On the same day, Q2 canola (Lindane-treated) was planted using a John Deer pan drill at the rate of 6 lb/acre, 6 inch row spacing and at half an inch depth. Moisture conditions at seeding time were adequate, however, the top soil was dried rapidly by windy, dry and hot conditions that persisted after seeding. Irrigation was not available in the area until later in May. Very few plants emerged (less than 5 % in each plot), therefore, on May 24th, 1 inch of water was added to the plots to induce germination. Cotyledon emergence was observed on May 30th. Drought conditions persisted throughout southern Alberta with very little rain from June to August. Therefore, to salvage the experiments, 3 inches of water were added between July 12th (11/2 inches) and July 19th (11/2 inch).

Flea beetle damage in 2001 was estimated at less than 10 % of cotyledon consumption in early to mid June, however with increasing temperatures and dry conditions, feeding continued on seedlings. Therefore, Decis (60 ml/ac) was applied to control flea beetles on June 22nd before the plants had reached the bud stage. A second wave of flea beetles immigrated into the north-west portion of the study site after an adjacent field of volunteer canola was mowed in early July; this wave could not be controlled and caused serious damage to some plots, particularly in the northern half of two blocks that were near the mowed area; these plots were excluded from seed yield analysis.

Experimental design

Objective1: Insecticide timing plot trial

Timing and frequency of insecticide application was studied using a completely randomized split block design with four replicates. Six treatments were allocated randomly to the six plots, each 10 x 10 m, comprising the sprayed half of each block: (i) bud spray, (ii) bud and flower, (iii) bud, flower and pod, (iv) flower, (v) flower and pod, and (vi) pod. Each half of the block had six unsprayed checks that were paired with the sprayed treatments.

In 1999, the late bud spray (Decis at 40 ml/ac) was done on July 6th when approximately half the plants were at the late bud stage (3.3) and the rest were at early flower or early bud. Because of extremely high numbers of cabbage seedpod weevils (up to 50 per sweep), the number of weevils after spray were still above the economic threshold of 3-4 per sweep and the plots were re-sprayed on July 11th. The flower and early pod sprays were done on July 20th and July 27th, respectively. Ten sweep net samples were taken along the southern 1/3 of each plot within 24 h before and after spraying and at the late pod stage (5.2-5.4) on Aug 10th.

On August 23rd, 2000, plants in two, 1 m^2 quadrats were harvested from the middle of each plot to estimate overall plant biomass and seed yield; one quadrat was laid on an area with a dense stand and the second one on an area with a thin stand. Furthermore, two plants were taken from the area near each quadrat and stored individually for future detailed assessment of total pods, blasted pods and number of pods with cabbage seedpod weevil exit holes. On August 25th, a strip 1.5 x 10 m was harvested with a plot combine from the northern 1/3 of each plot.

In 2001, the late bud spray (Decis at 40 ml/ac) was done on July 10th when the majority of the plants were at the late bud (bolting stage, 3.3) and the rest were at early early bud. The flower (4.1-4.2) and early pod (5.1) sprays were done on August 1st and August 9th, respectively. Ten sweep net samples were taken along the eastern 1/3 of each plot within 24 h before and after spraying and at the middle to late pod stage (5.2-5.3) on Aug 23rd. Plant density, including weeds, and distribution of crop stages were assessed on July 25-26th by placing two 1 m^2 quadrats near the middle or east third of each plot.

Lygus bug pressure on the plants was very high as predicted from earlier surveys conducted in flixweed in the spring. By the end of the growing season there were in excess of 60 per sweep net, including adults and old juveniles, in some of the untreated plots. A cursory examination of pod contents also suggested considerable seed damage (shrinkage) caused by lygus bugs. Because of the severe drought conditions and delays in germination, the majority of the plants (>95 %) in this trial were not exposed to the overwintered generation of cabbage seedpod weevils. By the end of July when most plants were in flower, activity of the weevil had decreased, therefore, data on exit holes was not collected from these plots. Information on weevil damage to the few plants that germinated early was collected from 10 plants per plot from an adjacent trial that was established to compare foliar insecticides vs seed treatments. Seed yields were measured from two 1.5 m strips taken from the western 1/3 of each plot using a plot combine.

Objective 2: lygus and weevil pest combination cage study

A randomized block design with the following six treatments was used: (i) check with no insect pests, (ii) low densities of 10 lygus and 10 weevils per cage, (iii) intermediate densities of 20 lygus and 20 weevils per cage (iv) high densities of 40 lygus and 40 weevils per cage, (v) lygus only at 20 bugs, (vi) csw only at 20 weevils. Each treatment was replicated 4 times with two sub-sample cages per plot. These density ranges reflected values below (10/cage), near (20/cage), and above (40/cage) economic thresholds for lygus bugs according to a previous study that had used the same cages (Wise and Lamb 1998). Weevil densities were somewhat arbitrary because they were based on preliminary data suggesting a sweeping efficiency of 20 % or about double that of lygus bugs (i.e. sweep nets catches represent only 20 % of the total weevil density in an area) and the assumption that flowering canola, where the weevils are concentrated, is easier to sample that podding canola. Using Wise and Lamb's (1998a) estimate that one arc (effectively 90°) with a sweep net covers approximately 0.66 m^2, 0.20 sweeping efficiency and a nominal economic threshold of 4 weevils per sweep, the density of weevils was estimated at 30 weevils per m^2 (4 weevils/sweep / 0.66 m^2 / 0.20); this translates to 24 weevils for a cage 0.81 m^2 or approximately 2 weevils per plant since we confined 10 plants per cage.

In 2000, this experiment was located about 50 m south of the above insecticide trial and the same agronomic practices were followed to establish the stand. Flea beetle pressure during emergence was very high and the area received Decis application as above. These plants could not be irrigated with the sprinkler system used for experiment one, however, about 28 gallons of water were added to individual cages on July 12th when plants were at the late bud - early flower stage. Cages (0.81 m^2) and 1.2 m tall were placed in areas with at least 10 plants of similar growth stage (pre-bud to ensure little damage by insects) on July 4th and 5th and any lygus bugs and cabbage seedpod weevils were manually removed on the same dates. All cages were inspected again for unwanted insects on July 11th prior to stocking (July 14th and 15th) and cages in the check treatment (no insects) were further cleaned of contaminants on August 1st. On August 29th, 2000, when the plants were at the 5.4 stage, all lygus, seedpod weevils and other insects were collected from each cage using a hand held battery operated aspirator. Levels of flea beetles and aphids were categorized into heavy, moderate or light infestation. On August 30th, four caged plants from each plot were bagged individually to quantify pod blasting and cabbage seedpod weevil exit holes. The remaining plants were harvested to estimate plant and seed biomass.

In 2001, this experiment was adjacent to the above insecticide trial and the same agronomic practices were followed to establish the stand. Seed used for this trial was also treated with Vitavax RS, however, flea beetle pressure during emergence was very high and the area received Decis application as above. This area was also irrigated on May 24th to induce germination. Cages (0.9 m x 0.9 m x 1.2 m) were placed in areas with at least 10 plants of similar growth stage (pre-bud to ensure little damage by insects) on July 4th and 5th and any lygus bugs and cabbage seedpod weevils were manually removed on the same dates. The plants were watered manually at 12 l/cage on July 5,9,12 and at 5 l/cage on July 20 and 27. The cages were stocked with weevils on July 13th and with Lygus keltoni from July 13-18. Despite manual watering, the plants in the cage study suffered from excessive flea beetle damage and drought stress and by the end of July it was clear that the few plants alive were not going to produce pods, therefore, this experiment was abandoned.

In the fall of 2001, a green house study was set up to replicate the field cage study abandoned because of drought and flea beetles in the summer. Two seedlings of a Q2 cultivar were transplanted into a two-gallon pot and enclosed with a fine mesh. Lygus bugs (only L. elisus) and cabbage seedpod weevils were obtained from lab colonies. Four replicate pots were allocated randomly to one of the following six treatments of a randomized block design: (i) check with 0 insects, (ii) 4 weevils, (iii) 4 Lygus, (iv) 2 weevils and 2 lygus, (v) 4 weevils and 4 lygus and (vi) 8 weevils and 8 lygus. Despite spraying the plants for aphids prior to adding the experimental insect pests, plants suffered from heavy aphid and thrips damage. An aphid bioncontrol was added but it was too late and plants failed to produce pods with full seeds. Lygus bugs were able to reproduce in some plants and up to 164 nymphs/adults were recovered per female stocked in the treatment with 4 lygus per plant.

RESULTS AND DISCUSSION

Insecticide timing trial: effects on pests and yield

In 2000, cabbage seedpod weevils (CSW) ranged from about 50 to 200 per 10 sweep sample (referred to as a "sample") at the bolting/early flower stage on 5 July 2000 (Fig. 1). In a nearby plot trial where plants flowered earlier because of seed treatment against flea beetles, CSW numbers were up to 500 per sample. Weevil numbers declined to less than 20 per sample at the early to mid-flower stage on 20 July 2000 in all treatments, including unsprayed checks. This pattern is indicative of natural mortality associated with weevil age. Clearly, plant phenology in relation to weevil physiology is an important factor and late planted canola or fields delayed because of drought or flea beetle feeding may not need spraying for weevils since they are already going to die from old age and not lay eggs by the time the plant reaches the critical mid-flower stage when small pods become available. Weevil numbers on 26 July 2000 at the early pod stage were negligible and likely represented some of the new generation weevils emerging from advanced plants in these plots or a nearby trial.

As expected from the low weevil activity in control plots during flowering, percent of pods infested by CSW was 8-9 % in all unsprayed plots. Only those plots sprayed at bud, flower and pod had significantly lower infestation levels at about 2 % compared to the checks at about 8 % (Fig. 2; ANOVA, DF = 1,6, F = 7.52, P = 0.034). The low level of infestation can be attributed to hot and dry conditions that allowed canola pods to mature at a faster rate than the weevil larvae and prevented their successful development and exit from the pods. Another possible reason for the low infestation level is that a nearby plot trial with seed treatments flowered much earlier and served as a trap crop by attracting the weevils and reducing the population loads at the insecticide timing trial. Infestation rates in the seed treatment trial reached up to 50 % in plots that flowered earlier.

In 2001, an extended spring drought (which continued into the summer) prevented germination of the seeds that had been planted at the end of April to attempt to synchronize canola with weevil activity. After irrigation in late May, canola development was further delayed by a record high infestation of flea beetles, despite seed treatment with Lindane and foliar sprays with Decis at the seedling stage. One day prior to the bud spray on 9 July 2001, there were less than 5 weevils per sample (Fig. 3) and around 10-25 per sample at the flower stage on 30 July 2001; these numbers are well below the economic threshold. No further data on weevil damage was collected from these plots.

In 2000, at the flower stage, lygus bugs were under 20 and 10 per sample in unsprayed and sprayed treatments (Fig. 4). At the early pod stage, control plots and those to be sprayed at pod had about 50 and 80 lygus per sample, respectively. Plots treated at bud and at flower had less than 10 lygus per sample and were significantly lower than those without treatment or only treated once at the bud stage (Fig. 4). A similar pattern was observed in 2001 (Fig. 5) but numbers were much higher, especially at the pod stage. Untreated plots reached over 240 lygus per sample, i.e. more than 10 times the recommended treshold of 2/sweep and even those treated once at the bud stage had more than 120 lygus per sample and significantly higher than some of the treatments sprayed at flower or twice at bud and flower ($DF= 6,21$, $F = 7.04$, $P = 0.003$, ANOVA on "ln + 1" transformed data). All treatments, however, exceeded the economic threshold at the pod stage suggesting that spraying earlier may be an economic disadvantage if lygus will still exceed thresholds and will require spraying at the critical stage when damage is known to occur. Canola plants can compensate for high levels of lygus during the early growth stage.

In 2000, yields, estimated by combining a 1.5 x 9m strip, ranged from 12 bu/ac in check plots to 21 bushels in plots sprayed at bud, flower and pod but the differences were not statistically significant (Fig. 6). Plots treated once at the pod stage yielded 19 bu/ac of canola seed. Yields from 1 m quadrats were also not statistically different and ranged from 17 to 28 bu/ac in check and bud-sprayed plots (data not shown). In 2001, yields differed considerably among treatments (Fig. 7). Plots that included a pod treatment or were sprayed twice at bud and flower yielded in excess of 11 bu/ac and significantly more than those unsprayed or sprayed only once at bud or flower (5 bu/ac or less, $DF = 6,7$, $F = 10.71$, $P = 0.0031$). Plots sprayed once at the pod stage yielded close to 11 bu/ac, about 4 bushels less than those sprayed three times ($P >$

0.05). There were less than 4 and 25 weevils per sample, well below thresholds, at the bud and flower stages, respectively, a day before spraying in 2001. This suggests that the yield response must not be related to weevils; flea beetles were extremely numerous and are likely to explain in part the yield responses to early insecticide spray.

Cage experiment

Very few weevils were extracted from the cages in 2000 (Fig. 8); numbers ranged from 2 to 5 per cage in the treatments stocked with 10 and 20 adults, respectively. Lygus bugs, on the other hand were much more numerous (Fig. 9) with numbers ranging between 60 to over 120 per cage in the treatments stocked with 10 and 20 lygus/cage, respectively. Weevil damage, measured as percent of pods infested per plant, was less than 12 % and did not differ significantly among treatments with weevils (Fig. 10). Weevil success as measured by pod infestation level was not affected by presence of lygus: the highest infestation was 12% in the treatment with 20 weevils and 20 lygus and was slightly higher than the treatment with 20 weevils and no lygus. This suggests that lygus do not interfere with weevils. Cages in both controls, with 0 weevils/20 lygus and 0 lygus/weevils had less than 2 % infestation levels, suggesting minimal contamination relative to stocked treatments (DF = 5,18, F = 13.39, $P < 0.001$). Abortion of reproductive structures (flowers and pods) were not affected by any level of insect pest or combination (Fig. 11). Clearly, flower and pod abortion or blasting is a process that occurs in the absence of lygus bugs and cabbage seedpod weevils.

Although caged plants were watered before adding insects at the early flower stage, yields per plant in 2000 were about a third of those observed in 1999 in other cage experiments. Nevertheless, there was a clear pattern of reduced seed yield per cage in treatments with combinations of 20 and 40 individuals of each pest type (Fig. 12). Plants appeared to tolerate combined densities of 10 lygus and 10 weevils or up to 20 individuals of either pest type; this pattern was more apparent when yield was expressed as a proportion of total plant biomass (g of seed per kg of plant mass, Fig. 13). These results have to be interpreted with caution because of the moisture stress and likely old age of cabbage seedpod weevils. Nevertheless, they confirm that combination of weevil and lygus at densities (20 of each pest/cage) around the economic threshold can cause yield losses under the experimental conditions experienced in 2000.

IMPACT

When and how often to spray for lygus and weevils?

The years 2000 and 2001 were extremely dry and irrigation was necessary to salvage the experiments. Yields in 2000 were not far from average values for a normal year because the plots had been in summer fallow in 1999, a year with excess moisture. In 2001, however, plants were clearly stressed and yields were much lower than the previous year. Hot and dry conditions caused canola to mature prematurely both years and probably prevented weevils from completing development to exit pods. Lygus bugs, however, thrived under such conditions, especially in 2001. In 2000, there were no statistically significant differences among the checks and sprayed plots, although plots sprayed at the pod stage yielded on average 6.5 bushels more per acre. In 2001, insecticide treatment made a big difference, because insects (lygus and also flea beetles) were much more numerous than the previous year and also moisture was more limiting. Moisture is clearly an important factor to consider before spraying as pointed out elsewhere by Wise and Lamb (1998b).

The normal practice in southern Alberta is to plant canola as early as possible to escape flower heat stress in July. Many growers will attempt to plant canola from the middle to the end of April (or even as early as the first week of April) and the majority will have planted it by the middle of May. Dry conditions, however, may prevent germination some years and also cause greater problems with flea beetles which will further delay time to flower and pod development. The strategy to manage insect pests (weevils and lygus) will vary depending on whether canola is going to flower early or late and also whether there are earlier flowering fields in the vicinity.

Assuming ideal growing conditions for a field planted in early April, no delays from flea beetle feeding (i.e. effective seed treatment or other control method) and no other fields flowering earlier, the grower would be well advised to monitor his or her field at the bolting stage for weevils. Chances are that such early-planted fields will accumulate large numbers of weevils and will require spraying. Because of the potential for re-invasion after spraying, the grower should wait a bit and allow the field to complete 20 % of its flowering before spraying (see fact sheet by Dosdall et al. 2001). Provided moisture is adequate and the plants are growing vigorously the field should not require spraying unless there is an unusual outbreak of other insects such as diamond back, bertha armyworm or lygus bugs. Most years, canola will escape damage from lygus because they reach high numbers late in the summer when the crop is at the ripening pod stage and no longer vulnerable. The greatest risk for this early-planted scenario is likely weevil re-invasion, therefore, monitoring, particularly the edges of the field, is crucial a few days after spraying until the crop has past the flower stage.

Most canola growers will plant in late April to early May. These growers fall into the category that may need to spray twice to control both pests. Because weevils are highly mobile they will concentrate in fields that flower earliest, therefore, it may not be necessary to spray an early May-planted field if a neighbour has a field that flowered a week before. It may be necessary to spray only the edges depending on the results from sweep net surveys of the field (10 sweeps at 10 locations). These fields, however, may reach the early pod stage at the time when lygus bugs are also abundant and may require spraying. Alternative cultural control methods such as an early planted canola trap strip to concentrate and control weevils need to be investigated to prevent the excessive spraying and economic losses in controlling both insect pest by multiple sprays.

Late planted canola (after middle of May) should not require spraying against the cabbage seedpod weevil because the adults would have invaded other fields planted earlier or they may be too old to lay enough eggs. Laboratory experiments are planned this winter to determine the influence of weevil age and overwintering time on female fertility. Canola flowering in mid July will have very few weevils and these will cause infestation levels below 12 % well below levels that cause economic yield losses that warrant spraying (Lerin 1984, Buntin 1999). Lygus bugs are likely to be a problem in late-planted fields, unless the growing season is wet and cool, which is ideal for canola and detrimental to lygus. Another serious pest risk in these fields is new generation weevils that can be damaging to late maturing canola pods; at this time control is not possible because of the pre-harvest interval restriction that applies to all insecticides.

In summary, based on plot trials reported here and elsewhere as well as field observations, timing of insecticide spray application will depend on seeding date, weather conditions during the growing season and abundance of pests in the field. Early-planted fields (early to mid April) should only require one application at the early flower stage to control cabbage seedpod weevils. Fields planted at intermediate dates, late April to early May, can be at risk from both pests and depending on insect densities will need spraying against the cabbage seedpod weevil most years at early flower and also against lygus in some years. Late planted fields will not require control against the cabbage seedpod weevil but depending on lygus numbers will need spraying at the early pod stage. These fields are also at risk from new generation weevils towards the end of the growing season, especially during years with cool summers. Based on current knowledge about canola agronomy and entomology, it is recommended that growers plant early, spray once in early flower (20 % bloom) if weevils exceed 4 per sweep. Farmers planting at intermediate dates and with neighbouring fields flowering before theirs, should consider spraying only the edges to control weevils or planting a trap strip to concentrate them and monitor the fields closely at early pod for lygus abundance.

Economic thresholds for pest combinations: lygus plus weevils

Economic thresholds for weevil/lygus combinations are preliminary at this point because the experiment was conducted only in 2000 and was partly confounded by drought. The results should be considered extreme for lygus damage because in a "normal" year, i.e. with average moisture, canola plants may tolerate higher levels of insect feeding than that observed in 2000. On other hand weevil effects were underestimated because they were added in mid July when adults may have been too old and also pods dried faster than usual because of drought and heat. Density combinations of 20 weevils and 20 lygus significantly reduced yields (7 g/0.81 m^2 cage) compared to the cages with no insects (18 g/0.81 m^2 cage). These yield values, although extremely low, represent a difference of about 2 bu/ac and assuming that the same difference prevailed in a normal year, it would make it economical to control with insecticides most years.

Converting densities of lygus and weevils from numbers per plant to numbers per sweep is necessary to allow producers to use this information. Such conversion rates are available for lygus bugs and are estimated at around 10 % by Butts and Lamb (1991a) and Wise and Lamb (1998a). For cabbage seedpod weevils these studies are in progress but preliminary data from 1999 suggested higher sampling efficiency of about 20 % from sweeping. The densities of 2 lygus and 2 weevils per plant used to stock cages at the beginning of flowering were chosen based on these estimates and were considered to represent values close to the current economic thresholds for the two pests (2 lygus and 4 weevils per sweep). Although the stages for economic thresholds for lygus are the early pod stage not the early flower when we added them to the cages. In summary, from this preliminary results it seems that the current suggested economic threshold of 2 lygus and 4 weevils per sweep can be used for pest combinations and should not be reduced when lower numbers of these pests co-occur. It must be pointed out that this experiment needs to be repeated in the field to confirm or reject the results from the unusual year.

Technology transfer activities

2000

Several extension presentations on the biology and management of the cabbage seedpod weevil and lygus bugs in canola were conducted during the spring, summer and fall of 2000. These included presentations to producers at meetings organized by the agro-chemical industry, a presentation to canola industry leaders who attended the Field Crop Science Workshop organized by Agriculture Canada, a seminar to researchers at the Saskatoon Research Centre and presentations to crop specialists at field days organized by Alberta Agriculture. Presentations were given at the spring and fall meetings of the Canola Council meeting in Edmonton and during their tour of Agriculture Canada's research plots in Lethbridge; a presentation was also given to the Alberta Canola Commission, southern Zone in Dec 2000. Furthermore, several interviews were published in newspapers, extension magazines or aired on local television dealing with issues of insect pest management in canola and a cabbage seedpod weevil strategy sheet for the 2000 growing season was prepared in collaboration with other specialists.

2001

Results from these ongoing studies to manage lygus bugs were shared with canola industry members via an oral presentation at the Alberta Agronomy Update held in January 2001 in Lethbridge. A written summary of this presentation entitled "Advances in the Lygus battle" was published in the conference proceedings (coauthored by Carcamo, Jones, Otani and Butts). A similar oral and written contribution was co-authored at the Western Canada Agronomy Workshop held in Lethbridge on July 4-6th, 2001 and published as part of the proceedings ("Cabbage seedpod weevil and Lygus bugs: New research developments on their biology and control", co-authored by Dosdall, Jones, Carcamo and Otani). Other extension activities included a publication in Agnet news (June 7/01) that warned producers about potential lygus bug pest problems based on their abundance in spring weeds and summarized monitoring, control strategies and ongoing research. A portion of this study was presented as a scientific poster titled "Chemical management of lygus bugs (Heteroptera: Miridae)" at the annual meeting of the Entomological Society of Canada on October 2001.

ACKNOWLEDGEMENTS

The following staff of the Lethbridge Research Centre are thanked for technical or field support: Carolyn Herle, Tracy Dickinson, Brie Hamblin, Quinn Lybbert, Todd Kemper, Jim Dalton, Carson Butts, Trina Fitzpatrick and Mike Balint. This study was funded in part by contributions from the Alberta and Saskatchewan Canola Producer Commisions administered by the Canola Council of Canada and by funds from the Matching Investment Initiative of Agriculture and Agri-Food Canada.

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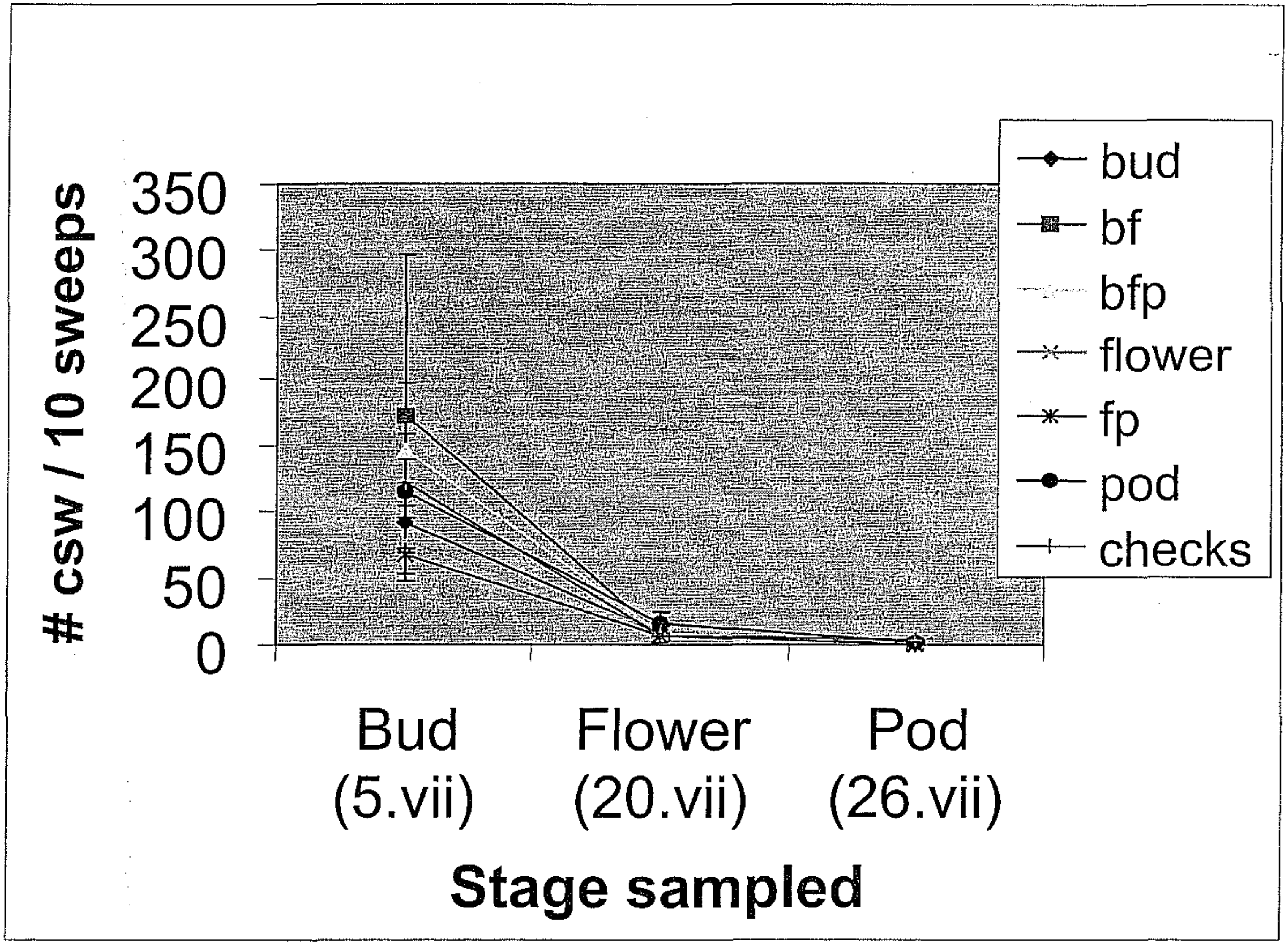

Fig. 1:Abundance of cabbage seedpod weevils (CSW) at plots of the insecticide timing trial one day before spraying in 2000. Entries are averages of 4 plots and one standard error. Six check plots were averaged in each block. Legend refers to crop stage when insecticide spray was applied; bf = bud and flower, bfp = bud, flower and pod, fp = flower and pod.

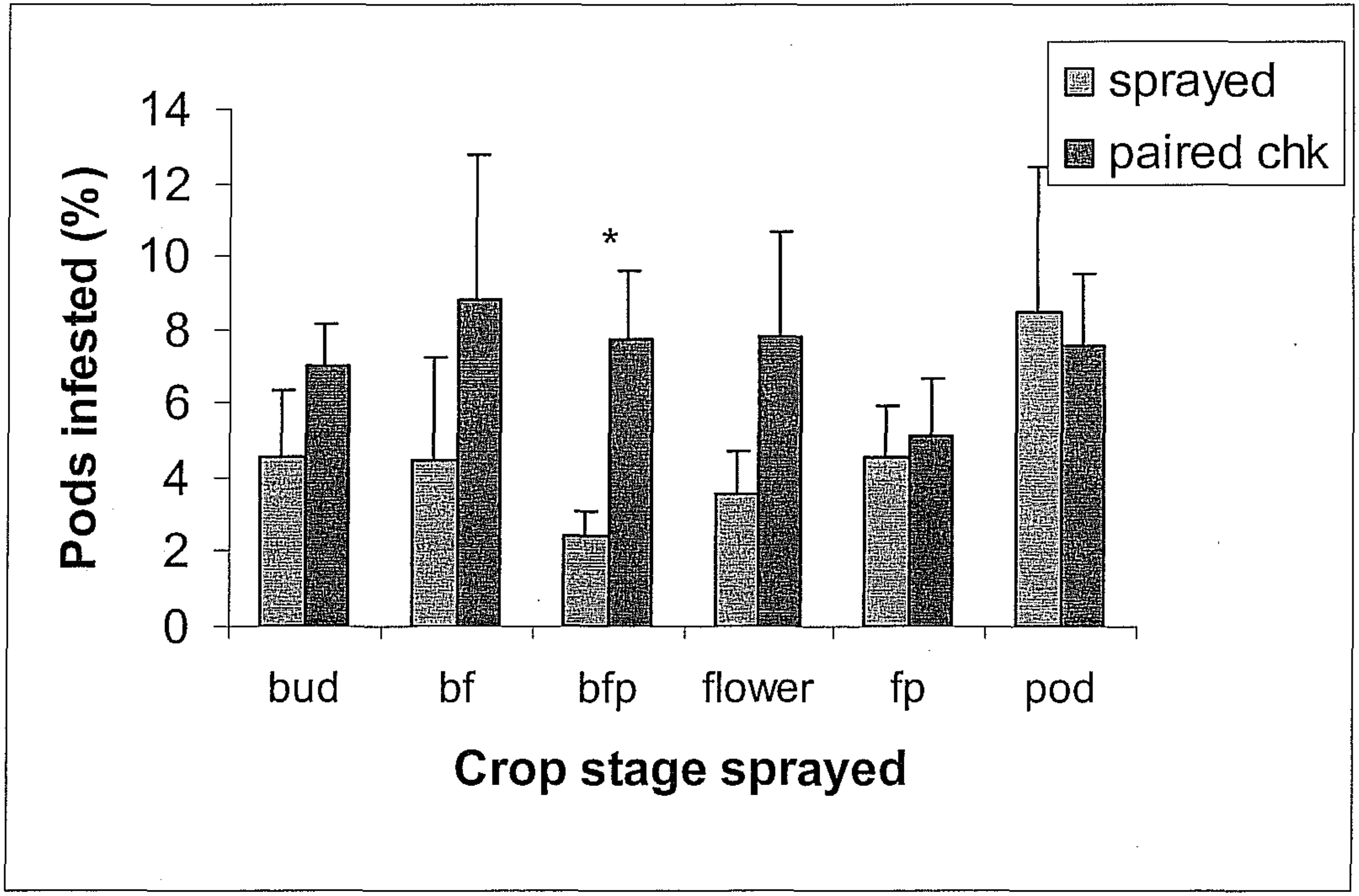

Fig. 2: Cabbage seedpod weevil damage to canola pods estimated from four plants per plot of the insecticide timing trial in 2000. Entries are averages of 4 plots and one standard error. Abbreviations: bf = bud and flower, bfp = bud, flower and pod, fp = flower and pod. * only plots sprayed 3 times had significantly lower infestation levels than the paired unsprayed checks (ANOVA, DF = 1,6, F = 7.52, P = 0.034).

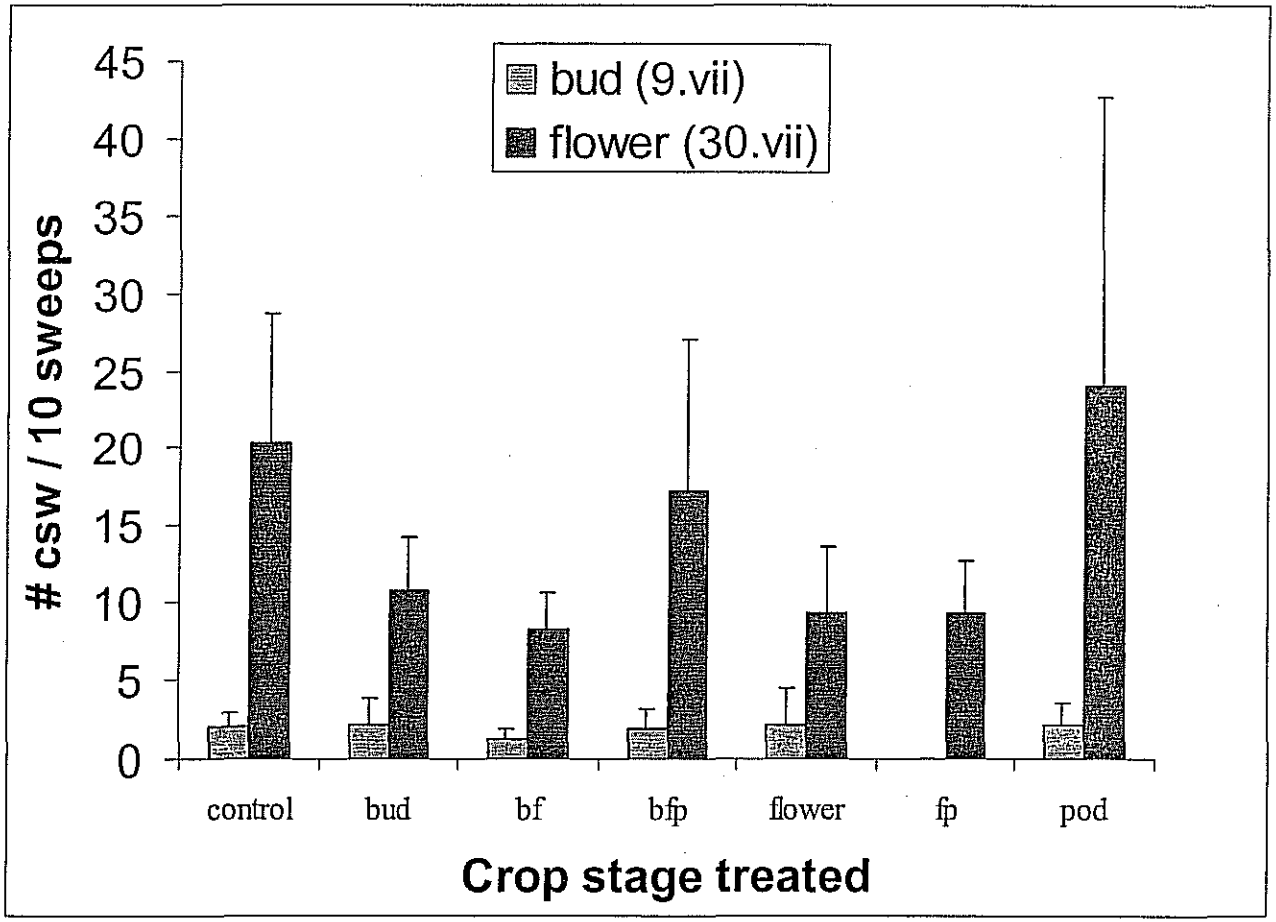

Fig. 3:Abundance of cabbage seedpod weevils (csw) at plots of the insecticide timing trial one day before spraying at bud and flower stages in 2001. Entries are averages of 4 plots and one standard error. Six check plots were averaged in each block.
Horizontal axis labels refer to stage when insecticide spray was applied or scheduled.
Abbreviations: bf = bud and flower, bfp = bud, flower and pod, fp = flower and pod.

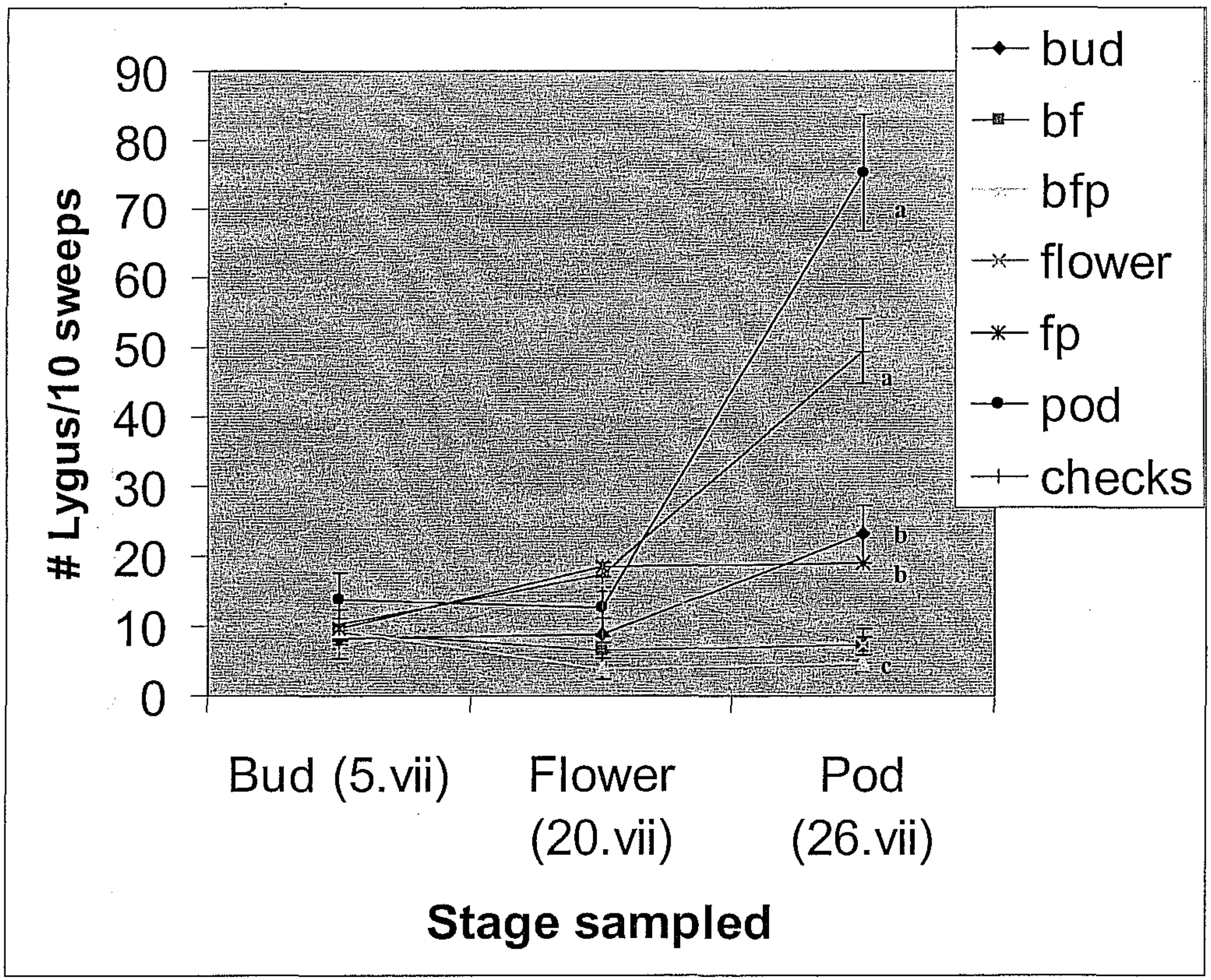

Fig. 4:Abundance of lygus bugs at plots of the insecticide timing trial one day before spraying in 2000. Entries are averages of 4 plots and one standard error. Six check plots were averaged in each block. Legend refers to crop stage when insecticide spray was applied; bf = bud and flower, bfp = bud, flower and pod fp = flower and pod. Means for pod stage not sharing letters are significantly different, LSD test, $p < 0.05$.

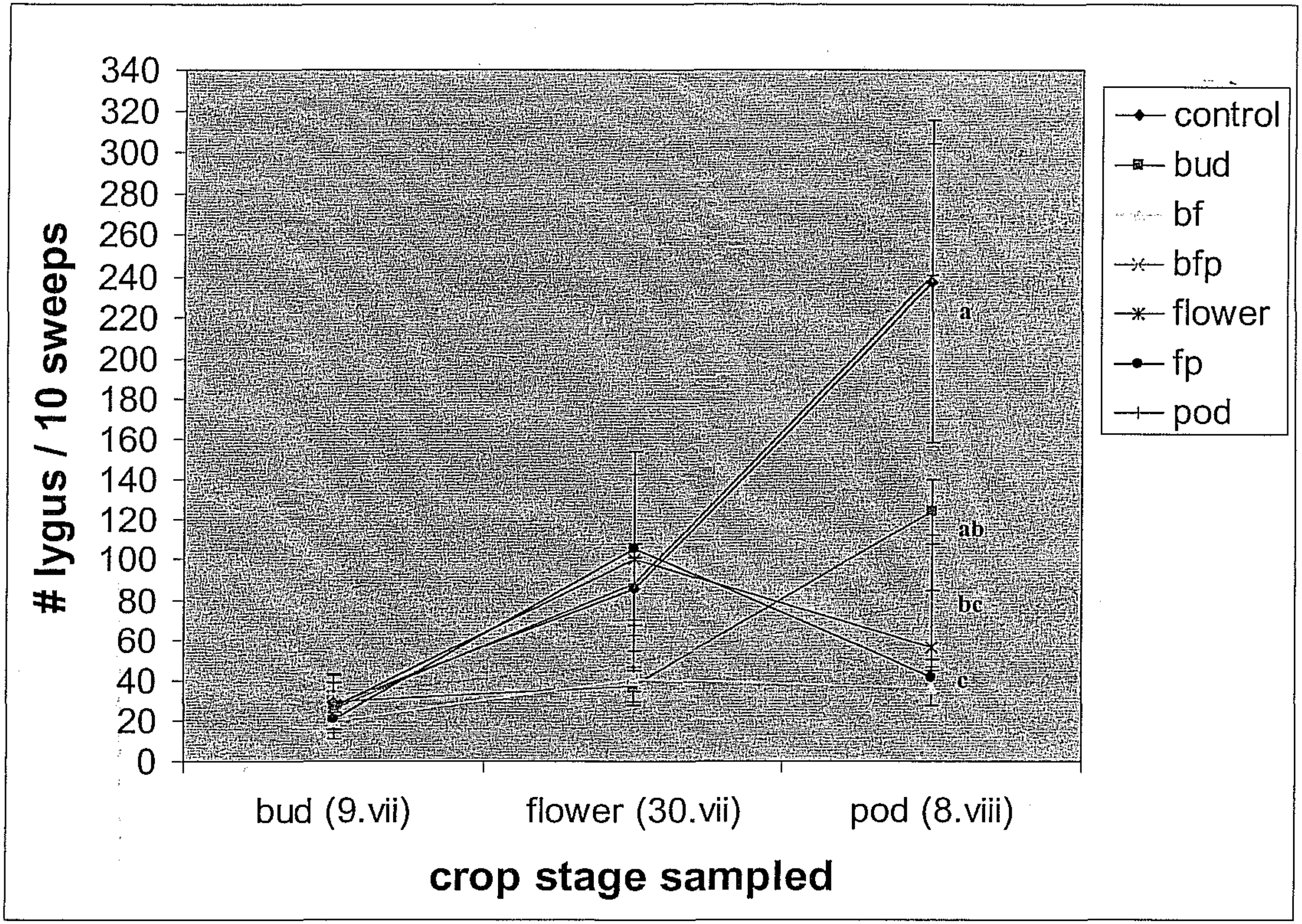

Fig. 5:Abundance of lygus bugs at plots of the insecticide timing trial one day before spraying in 2000. Entries are averages of 4 plots and one standard error. Six check plots were averaged in each block. Legend refers to crop stage when insecticide spray was applied; bf = bud and flower, bfp = bud, flower and pod fp = flower and pod. Means for pod stage not sharing letters are significantly different, LSD test, $p < 0.05$.

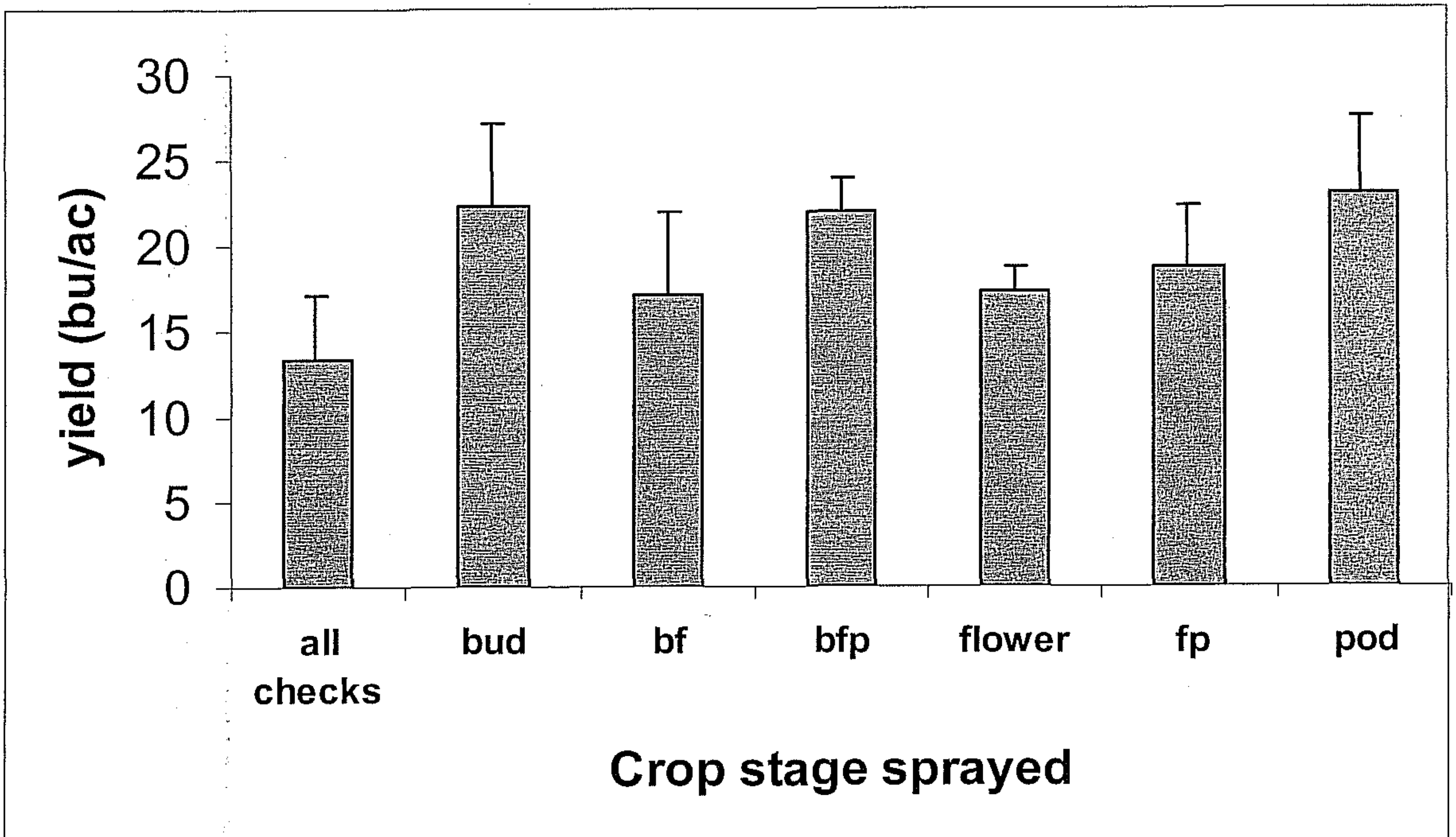

Fig. 6: Canola seed yield at Victory Church insecticide timing plots from 1.5 x 9 m strips. Entries are the average of 3 plots for sprayed treatments and pooled averages of 3 blocks for the checks; error bars represent 1 se. Means are not significantly different, LSD tests after one way ANOVA, $p>0.05$.

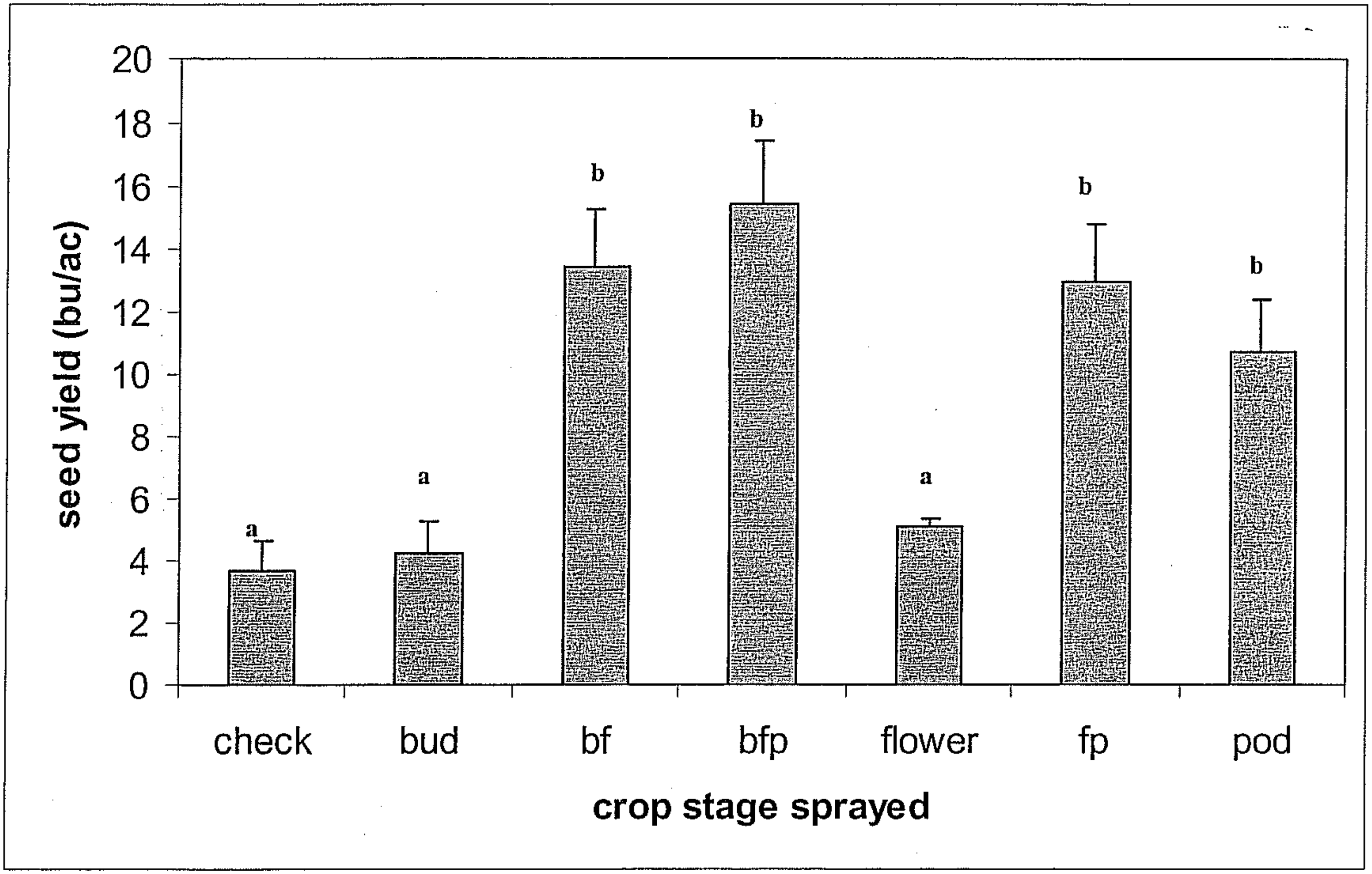

Fig. 7: Canola seed yield at Victory Church insecticide timing plots from 2, 1.5 x 9 m strips in 2001. Entries are the average of 2 plots for sprayed treatments and pooled averages of 2 blocks for the checks; error bars represent 1 se. Means not sharing letters are significantly different, LSD test, $p < 0.05$.

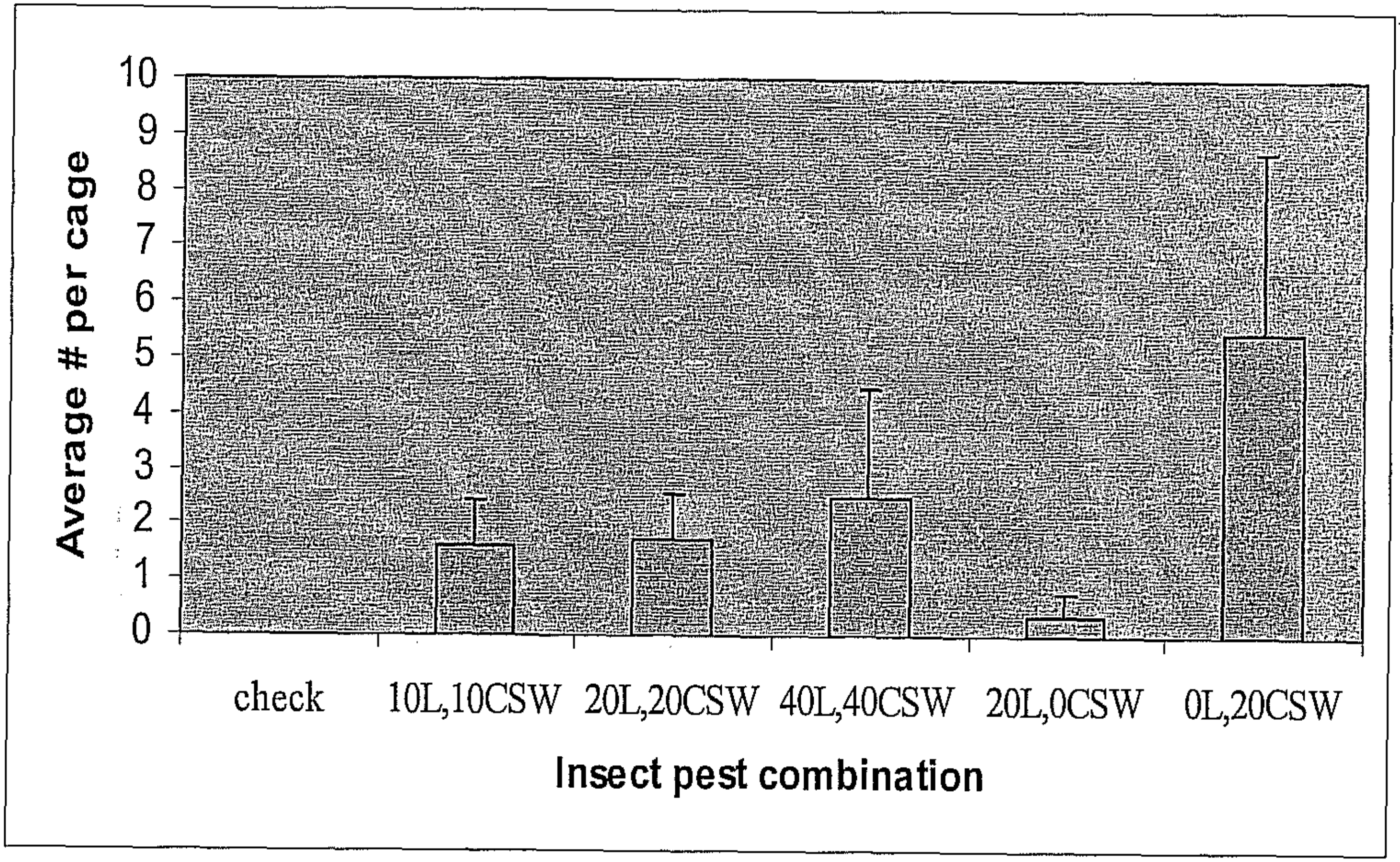

Fig. 8: Average number of cabbage seedpod weevils extracted on August 29th, 2000 from cages used to study effects of insect pest combinations on canola yield.

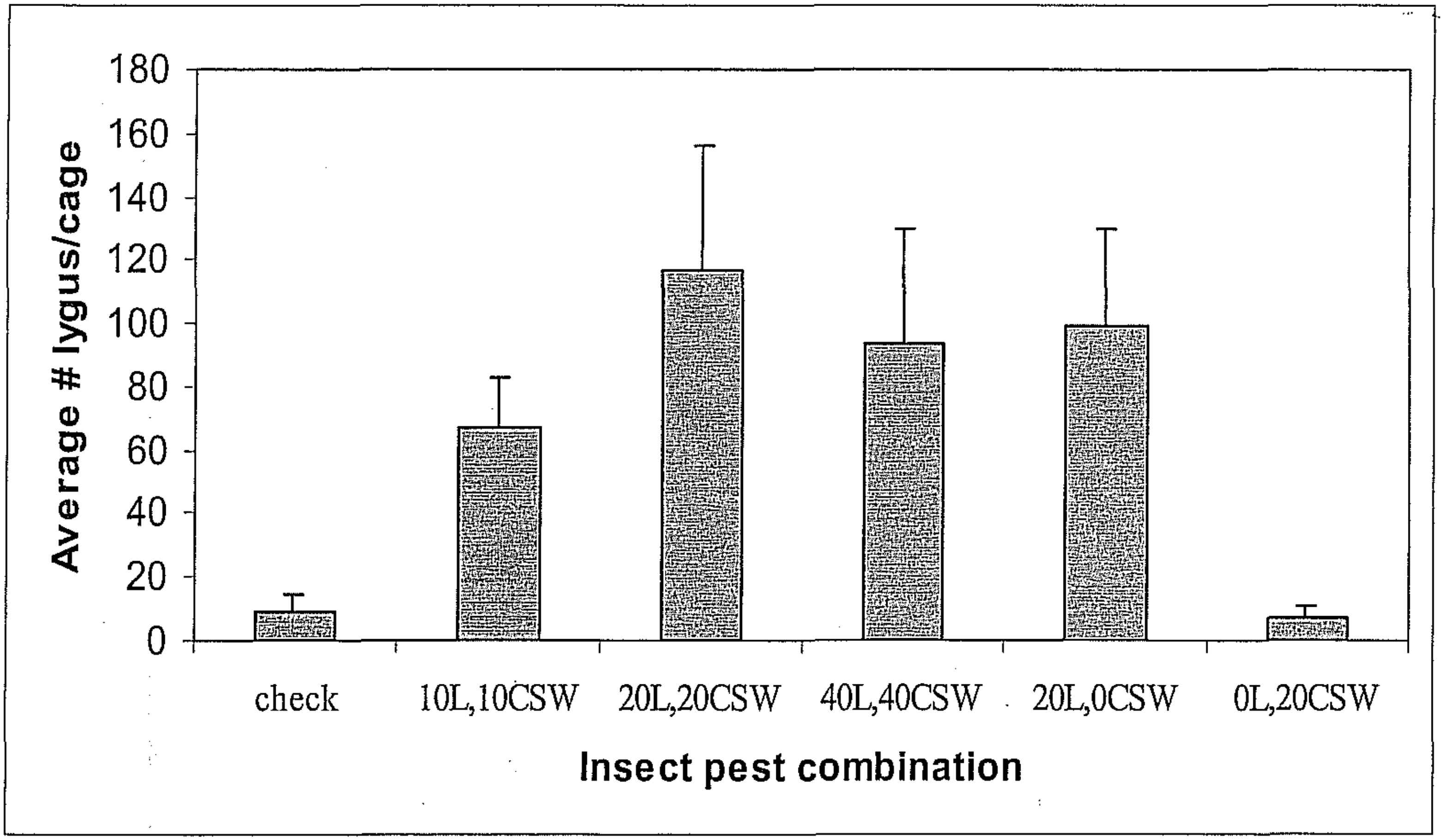

Fig. 9: Average number of lygus bugs (adult and nymphs pooled) extracted on August 29th, 2000 from cages used to study effects of insect pest combinations on canola yield.

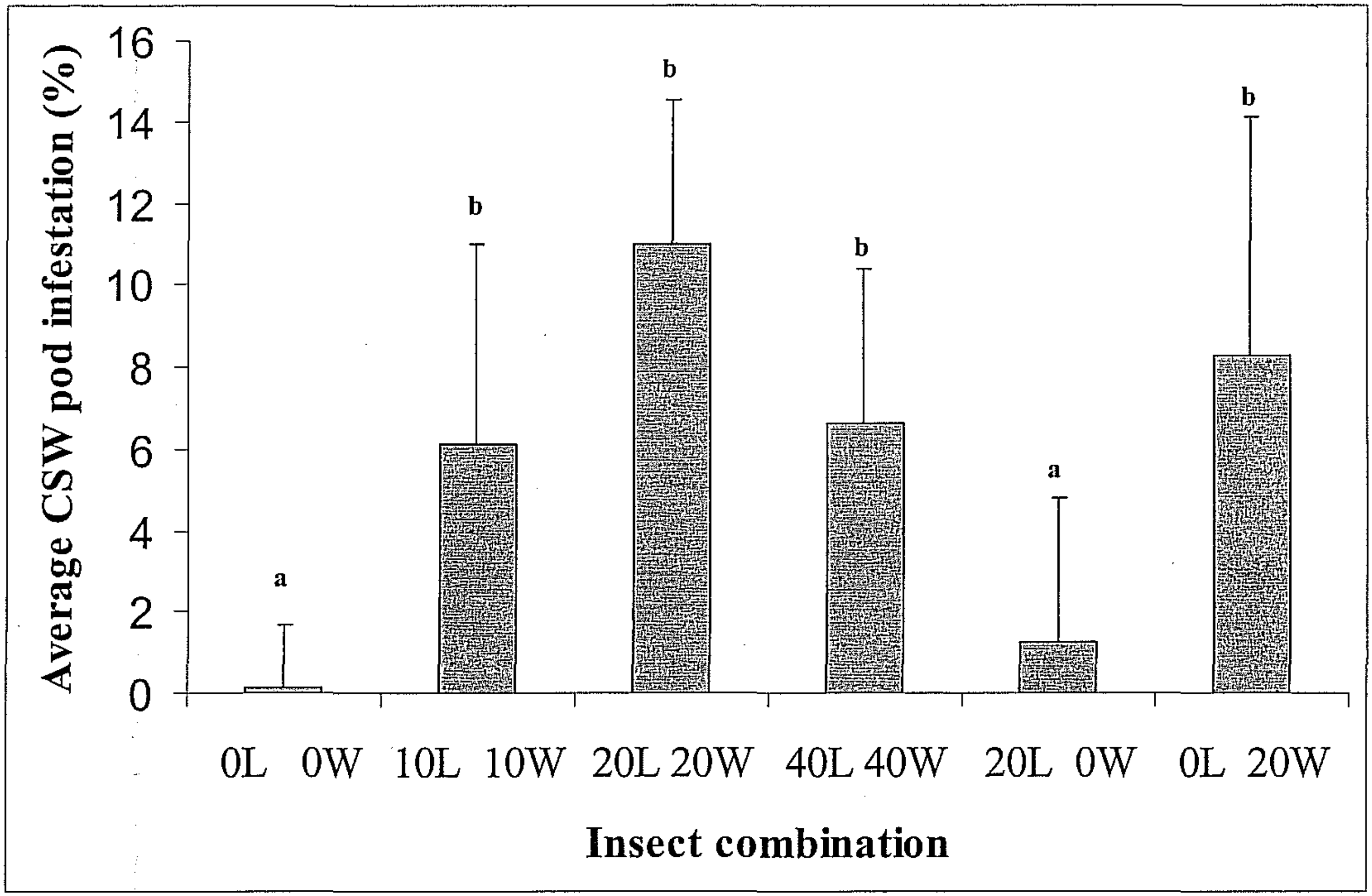

Fig. 10: Cabbage seedpod weevil pod infestation levels in cages used to study effects of insect pest combination on canola yield in 2000. Only treatments with no weevils had significantly lower infestation levels (Ln + 1 tranformed data, LSD test after one way ANOVA, $p < 0.05$).

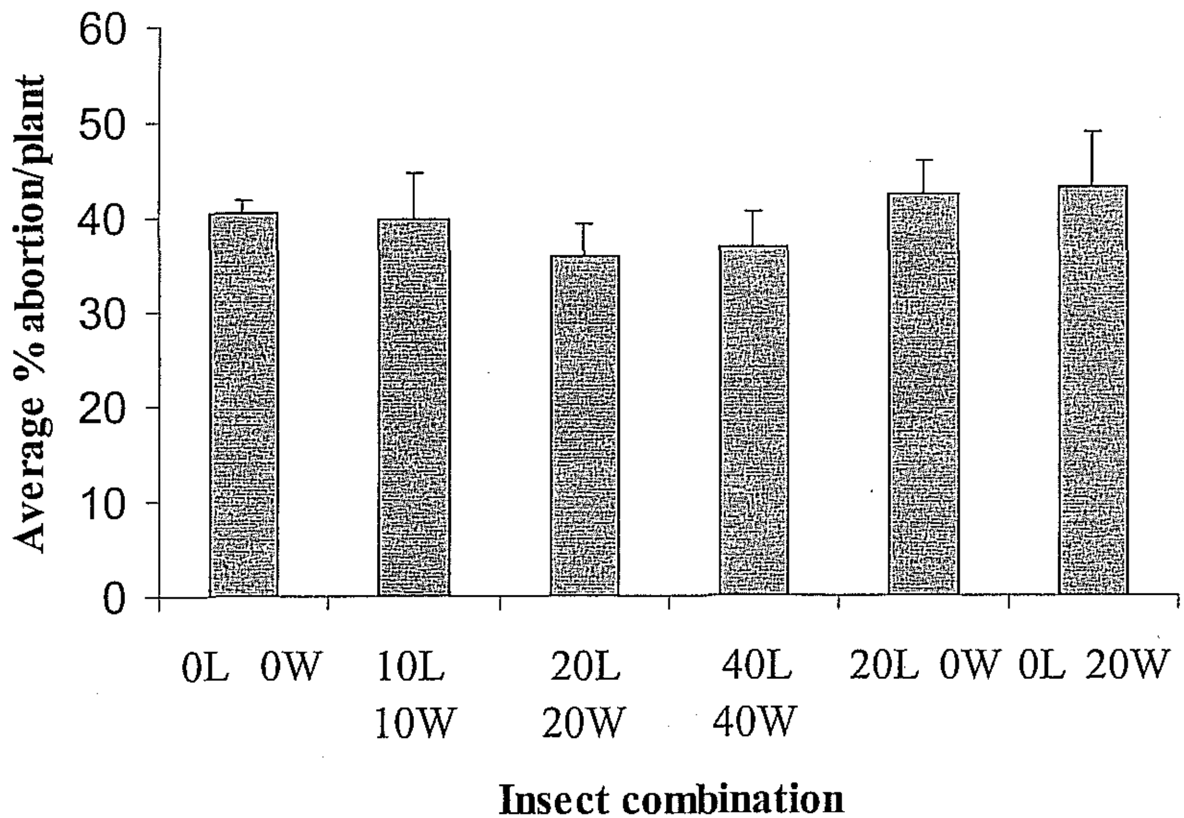

Fig. 11: Abortion of buds and flowers in cages used to study effects of insect pest combination on canola yield in 2000. There were no significant differences among any treatments, ANOVA, $p > 0.05$.

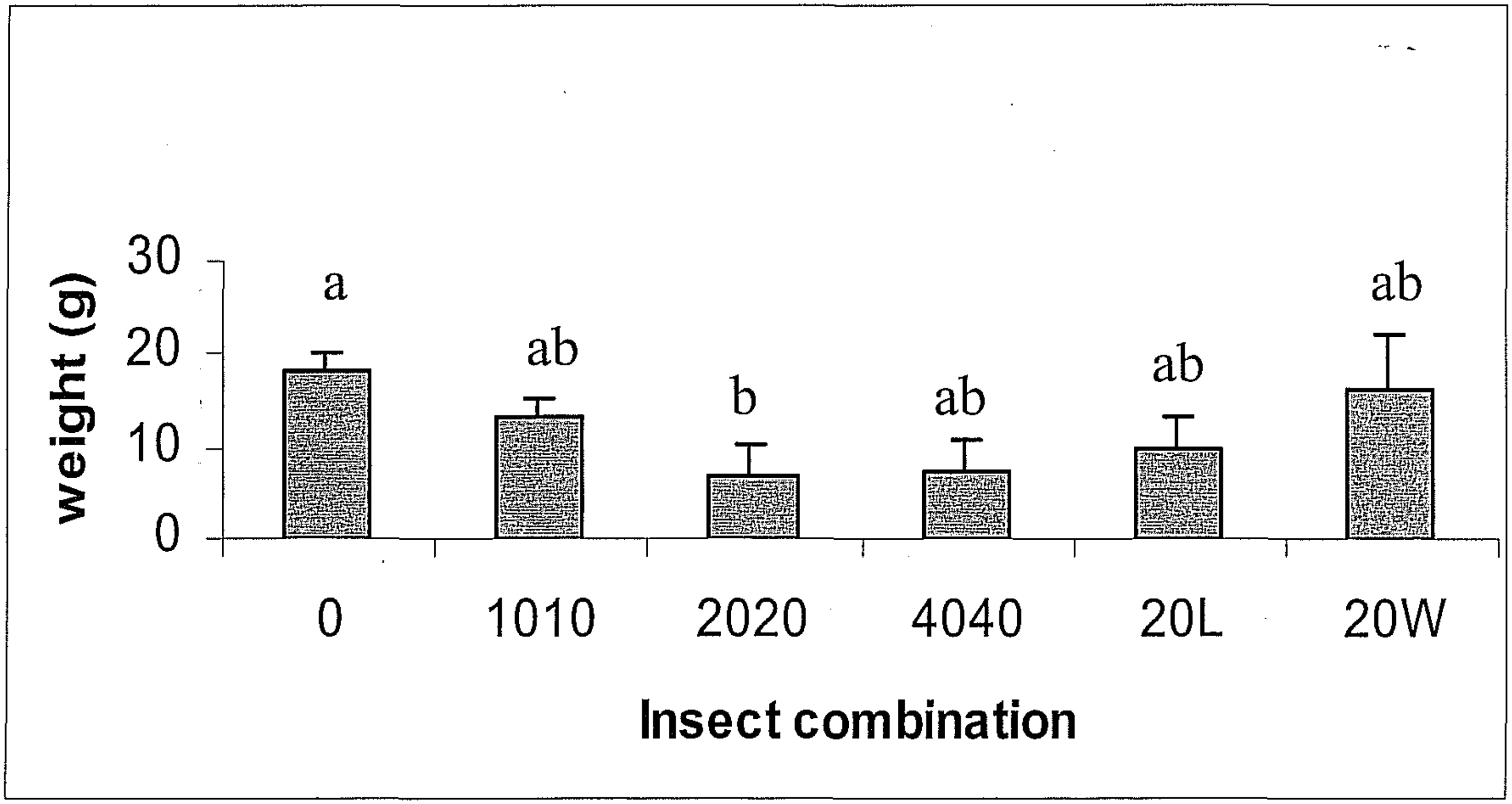

Fig. 12: Weevil and lygus pest combination effects on seed yield. Histograms are averages of 4 plots (two cages averaged per plot). Means (+ 1 se) not sharing letters are significantly different according to ANOVA and LSD test, $p < 0.05$.

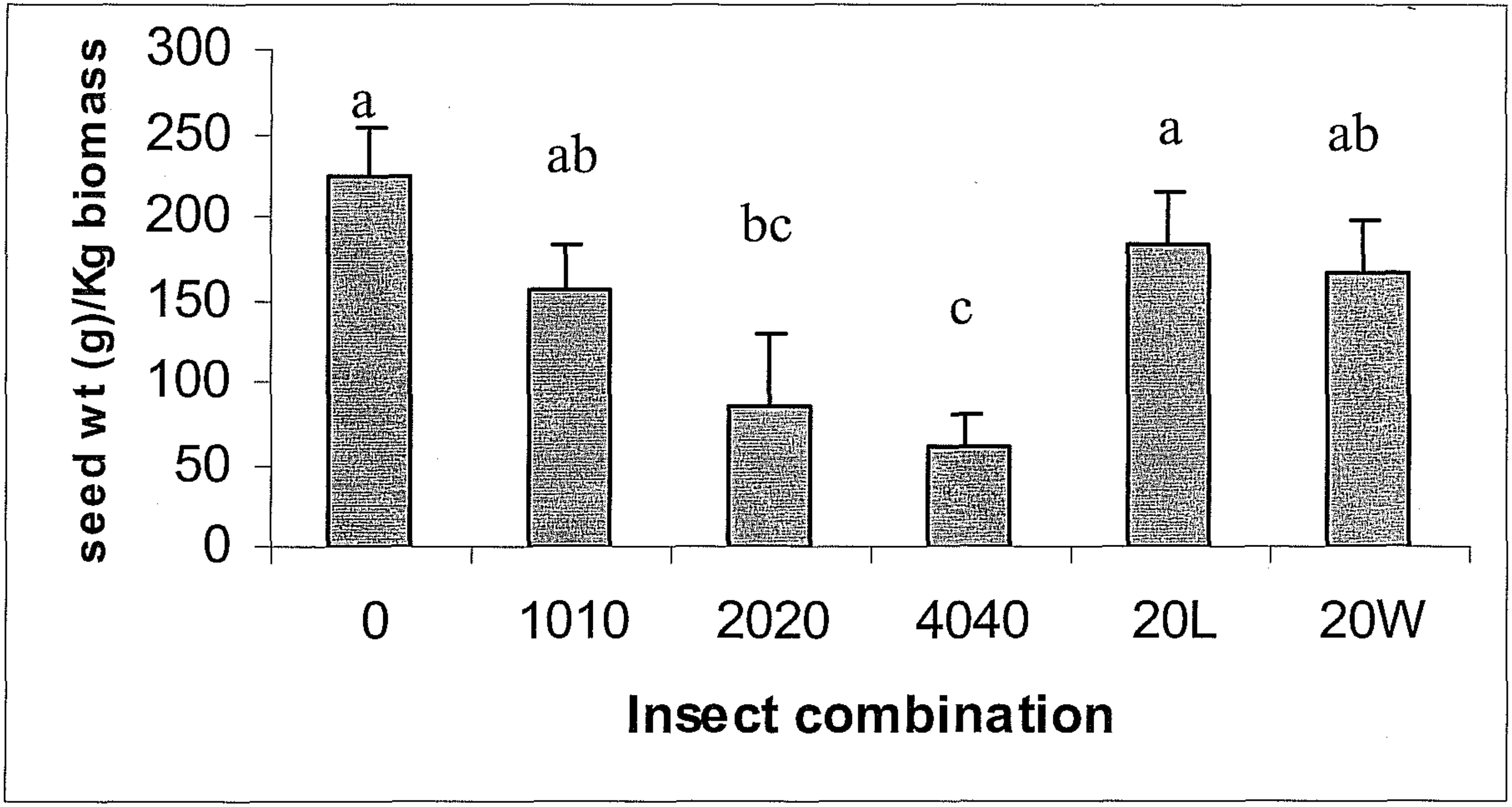

Fig. 13: Weevil and lygus pest combination effects on biomass-adjusted seed yield (g of seed per kg of total biomass). Histograms are averages of 4 plots (two cages averaged per plot).
Means (+ 1 se) not sharing letters are significantly different according to ANOVA and LSD test, $p < 0.05$.