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Project report submitted to the Organic Farming Research Foundation:

Project Title:

Flame weeding in organic vegetable production

FINAL PROJECT REPORT

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ABSTRACT

Flame cultivation was compared to traditional hand-weeding method of weed control in seeded onions and carrots during 1995 at an organic farm in Bramber, Nova Scotia. Weed effect, labour requirement and yields were compared. The results of seven different experimental treatments on flame weeding and hand-weeding are reported. The most resistant weeds to different treatments is included. Yield determination, labour requirement for hand-weeding and weed counts were used to evaluate the treatments. Early flaming is necessary to improve weed control, to reduce competition period. Results of both crops showed that pre-emergence flaming application is able to reduce weed number by 64 to 92%.

Results of this one year experimental work showed flame cultivation is a very labour saving and profitable support for the organic farmers. Growing seeded onions and carrots using flaming will be less expensive than traditional hand-weeding method; mainly since the labour cost for hand-weeding will increase . In onions, with pre-emergence flaming and post-emergence flaming at 15≥ cm. height, the labour requirement was lower than with just pre-emergence flaming method and considerably lower than with purely hand-weeding method, but flaming two times gave more yield reduction. In carrots the labour requirement was more than twice as much with the treatment with two hand-weedings than the treatment with pre-emergence flaming and two hand-weedings.

Pre-emergence flame cultivation caused a slight yield reduction. Pre-emergence flaming involves relatively few problems even though the time of the treatment is very critical. Selective flaming in the growing crop, on the other hand, requires precision with great risk of damage to the crop plant. Post-emergence flaming have showed further yield reduction.

INTRODUCTION

Flame weeding has been a controversial issue since it was introduced 58 years ago in North America. Today it is a bigger topic than ever. The idea behind flame weeding is to kill weeds with an intensive wave of heat, without disturbing the soil or harming the crop root system. Since all plants are composed of tiny cells filled largely with water, a thin blast of heat directed at the stalk will boil the water within the cell. The pressure generated by this expanding water will then explode the cell it self, rupturing a cross section of the stalk. When this happens plant food and water cannot move from roots to leaves and the plant withers and dies.

In order to rupture the cells, temperature within the cell must reach 100°C for a period of about one-tenth of a second (Mattsson 1989). Here lies the entire key to successful flaming. As a plant grows it develops an outer skin or bark that protects it from heat. The thicker this skin and the larger the plant the more heat required to boil the cell moisture.

The trick is to apply heat when weeds are small. To accomplish this, three methods are used: Selective flaming, nonselective flaming, and pre-emergence flaming. In selective flaming the flame is usually directed across the crop row. If the crop is larger than the weed, with a more fully developed protective skin, the heat can kill the weed without damaging the crop. The heat is controlled by varying the speed at which the flame is passed over the field, and the position of the burner with respect to the plant. If the difference between protective covers of the crop and the weed are more critical, selectivity is obtained by directing the flame pattern towards the weeds and away from the crop. This is usually accomplished by parallel flaming or by using burners with more precisely controlled flame patterns.

In many cases the stage of weed growth will be too similar to that of the crop to allow selective flaming. Under this condition nonselective flaming is applied to such crops on corn and onions. At an early stage of growth the terminal buds of these crops are still below ground. General flaming will kill both weeds and the tops of the crops, but the crops will sprout back from their terminal buds, usually with a head start on weeds. From this point on selective flaming can be used.

The third approach, pre-emergence flaming, is less critical on all crops. If weeds have emerged before the crop they can be flamed back while the crop is still protected by soil. With weed growth retarded the crop can get a headstart. Selective flaming can then be used to keep the weeds under control.

According to Johan Ascard (1989) in onion sets the weed control could be managed with three flaming until end of June, after which hand-weeding was needed. With three flamings the labour requirement was considerably lower than with chemical control. In seeded onions the labour requirement was more than twice as much with thermal than when chemical was used. In few crops such as potatoes, corn and onion sets, all or most of the weeds can be managed without hand-weeding by means of mechanical and thermal methods (Geier & Vogtmann 1986; Vester, 1987).

Parish (1989) conducted laboratory tests on rye grass and mustard plants and he found that the effect of gas burner depended on its design and angle to the horizontal, and from his tests it was determined that the height of the burner above the ground controlled the effect on ryegrass

but not on mustard.

Bertram 1992 studied the heat transfer from the weed flamers to the plant and the factors which have effect on it. A mathematical model of flame formation was developed and used to determine the influence of different equipment designs on heat flows under a cover.

Geier & Vogtmann (1986) tested and compared row brush hoe with other hoeing equipment. They found that the efficiency in destroying weeds with this machine is a lot better than common hoeing systems. According to Kress, W. (1987), despite a fine and loose top layer that the brush hoe will form, there seems to be no danger of soil erosion.

METHODS AND MATERIALS

The organic weed control project at the Nova Scotia Agricultural College was initiated in 1995 as a cooperative project between Agricultural Engineering Department and Sunset Garden, organic farm, in Bramber Nova Scotia.

The primary research was mainly the responsibility of the Agricultural Engineering Department with advisory assistance being obtained from the Plant Science Department and from the Plant Industry of the Nova Scotia Department of Agriculture and Marketing weed specialist.

The investigation examined the effect on weed growth and labour requirements in field trials in organic farming. Major emphasis has been placed on weed control in onions and carrots.

The number of experimental treatments have been seven. All the trials were made as randomized block experiment and four replicates have been used to rule out as many variables as possible in the verification of test results.

This one year study was devoted primarily to observing seven different weed control treatments to determine those most effective for further study in the following years. twenty eight trials were established 16 for onions and 12 for carrots.

Four treatments were used in onions:

T1 - control

T2 - two hand-weeding

T3 - pre-emergence flaming; two hand-weedings

T4- pre-emergence flaming; post-emergence flaming; two hand-weedings

Three treatments were used in carrots:

T1 - control

T2 - two hand-weedings

T3 - pre-emergence flaming; two hand-weedings

Pre-emergence flaming in carrots was conducted on June 9, 10 days after carrots were planted. In onions pre-emergence flaming was carried out on may 28, 12 days after planting and 2n^{d} flaming on June 30, when onions were 15 >: cm. high. The weeds were counted before flaming and after flaming. Onions were flamed from both sides on the 2"^{d} flaming. The time required for hand-weeding and flaming was measured and recorded. Observations were made for the determination of the weeds which most resisted the flame treatment. In all treatments the weeds between rows were mechanically controlled by 3-4 times by S-tines.

RESULTS AND DISCUSSION

Under organic farming conditions the labour requirement is the highest cost in the production of vegetable crops. In both carrots and onions there is a need for large hand-weeding inputs due to the weak competitive ability of both crops. Growing onions and carrots require a large amount of hand-weeding in the row, even when very accurate mechanical row-cultivation is performed.Weed control with flame is, profitable and very labour saving. The results proved that a considerable reduction in number of weeds and consequently in labour requirements for handweeding can be achieved, as well in onions, as in carrots. The yields from flamed trials have showed a slight reduction in both crops.

Pre-emergence flaming showed to be very important treatment and very effective in controlling weeds, and thereby, less hand-weeding will be needed. Pre-emergence flaming should be applied as close as possible immediately before the crop emerge. The efficacy of each treatment in onions on weed control is illustrated in Fig.1. The most effective application was pre-emergence flaming in treatments T3 and T4, and the least effective application on weed control was in the 2nd flaming at $\geq$15 cm. in treatment T4. This is because selective flame cultivation in onions is a very precise operation which requires great accuracy and skills for good results. The risk of damage is great. It is interesting to see from Fig. 1 that actually with pre-emergence flaming we were able to control weeds at higher rates than hand-weeding, because with pre-emergence flame cultivation small weeds will be burnt down while with hand weeding will be ignored and left in the field..

The most resistant weeds for hand-weeding (T2) in onions were common chickweeds, crab

grass, lambsquarters, ox-eye daisy, tufted vetch and redroot pigweed. In 2nd flaming the most resistant weeds were big weeds such as lambsquarters and weeds sitting on ground such as chickweed. The best burnt down were tufted vetch, bull thistle and cudweed. Pre-emergence flame cultivation in onions reduced the number of weeds by 92% and in carrots the number of weeds was reduced by 75% (Fig. 2).

Results of this experimental work showed that there is a correlation between the number of weeds and labour requirements. From Fig.3 it is clear to notice that the average labour requirements in onions for hand-weeding, which was previously flamed before and after the crop have emerged, was about one third in comparison with purely hand-weeding. The average labour requirements for hand-weeding in treatment T3 which consists of just pre-emergence flame cultivation was about half of that required for treatment T2.

On average the labour requirements for hand-weeding in carrots, is also shown in Fig. 3. The labour requirement for hand-weeding in treatment T2 with pre-emergence flaming, was 365 minutes per 100 m^2, compared to 583 minutes for treatment T2 with just hand-weeding.

In onions, the average yields are illustrated in Fig.4 were slightly higher in hand-weeded trials than the trials in treatment T2 with pre-emergence flame cultivation, the yields per hectare were 19,750 kg compared to 17,560 kg/ha in T2. Further yield reduction of onions in comparison with trials which were not flamed, were found in trials which were flamed twice, before the crop have emerged and after the crop have emerged. The yields were 14,540 kg/ha.

Similarly, it was found that with pre-emergence flame cultivation the carrot crop had less yields than without any flaming (Fig. 5). A reduction in yields of 1,498 kg/ha has occurred.

CONCLUSIONS AND RECOMMENDATIONS

Flaming seems to be headed for more widespread use in some areas. It is not the mysterious gremlin it was a few years ago, and new equipment coupled with increased experience promises to make it an even more effective method of controlling weeds. This is particularly true in high labours crops such as vegetables.

How good is flame weeding? The best answer is that it is not quite as good as the industry maintains, but much better than was generally believed a few years ago. If flaming is to be effective a few points should be considered. First, the farmer must know very well his

equipment and must follow the manufacturer's recommendations. Flaming is a precise, finely balanced operation and cannot be used by every hired hand who comes along. Flame cultivation may have more potential in the drier areas where pre-emergence herbicides have been less effective, and in wet soils where it is impossible to use mechanical cultivators.

What are the advantages of flame weeding? Supporters point out that soil is undisturbed and crop root systems are not damaged. Deeper moist soil is not turned up for exposure to the air and loss of moisture. Of major importance to weed control, the flaming proponents say, is the fact that weed seeds are left deep in the soil rather than being plowed to surface, and fewer of them will germinate during the season. Flaming can be carried out in to a field that is too wet for mechanical cultivation, controlling weeds before they get out of hand. Flaming also eliminates chemical residues in the soil that might cause trouble for later crops at commercial farms.

This one year of research at Nova Scotia Agricultural College on the use of flame cultivation for the control of weeds in vegetable crops in organic farming have shown the following:

1. Early flaming is necessary to improve weed control, to reduce competition period.
2. From field observation, it was noticed that, the smaller the weeds, the easier the control. Best control is obtained by flame cultivation when broad leaves and grasses are less than 5 cm.
3. The effect of flaming on weeds can be observed within few minutes after the flame operation.
4. Pre-emergence flaming involves relatively few problems even though the time of the treatment is very critical.
5. Pre-emergence flame cultivation in the short run has shown the best weed effect.
6. Selective flaming in the growing crop, requires precision with great risk of damage to the crop plant.
7. Flaming weeds without crop damage becomes increasingly difficult as the weeds grow larger and together.
8. Onions has sufficient heat tolerance for control of most weeds and grasses.
9. The tests of this one year study indicate that flaming may find an important spot in a weed-control program for seeded onion and carrots.
10. Results of this study showed that flame cultivation is a very labour saving and profitable

support for organic farmers.

11. Growing seeded onions and carrots using flaming will be less expensive than traditional hand-weeding method; mainly since the labour cost for hand-weeding will increase.
12. Pre-emergence flaming caused a slight reduction of yields in both onions and carrots.
14. From an economic standpoint, weeds between the rows should be controlled by mechanical method of cultivation, which is cheaper than flame cultivation or traditional hand-weeding methods.
13. Further reduction in the yields of onions occurred when it was flamed twice, before the crop has emerged and after.
15. Growing onions and carrots require large amounts of hand-weeding in the rows, even when accurate mechanical row-weeding is performed.
16. Under organic farming conditions the labour requirement is the highest cost in the production of onions and carrots.
17. Flame cultivation may also be an interesting alternative or complement to herbicides in conventional forms of production, particularly if there are problems with herbicide-resistant weeds.
18. Flame cultivation is recommended to be used in all organic farms with considerable vegetable areas.
19. In order to meet the demands for cheaper and healthier food there is a need for a new weed control method such as flame.
20. The labour saving effect of pre-emergence flaming was less than post-emergence flaming in onions, consequently, in onions it is mainly pre-emergence cultivation should be recommended.
21. Tractor mounted flame weeders are recommended to be used on organic farms with large ares of vegetable production.
22. Flame weed control should not be overlooked as a part of an integrated weed control program with herbicide resistant weed species.
23. For better weed control, flame cultivation will also be of interest as a supplement to chemical and mechanical weed control methods in conventional commercial farming.
24. Pre-emergence flaming has the potential to replace nonselective herbicide such as Gramoxone used in so called "stale seedbed" method, to burn off the weeds before crop emergence.

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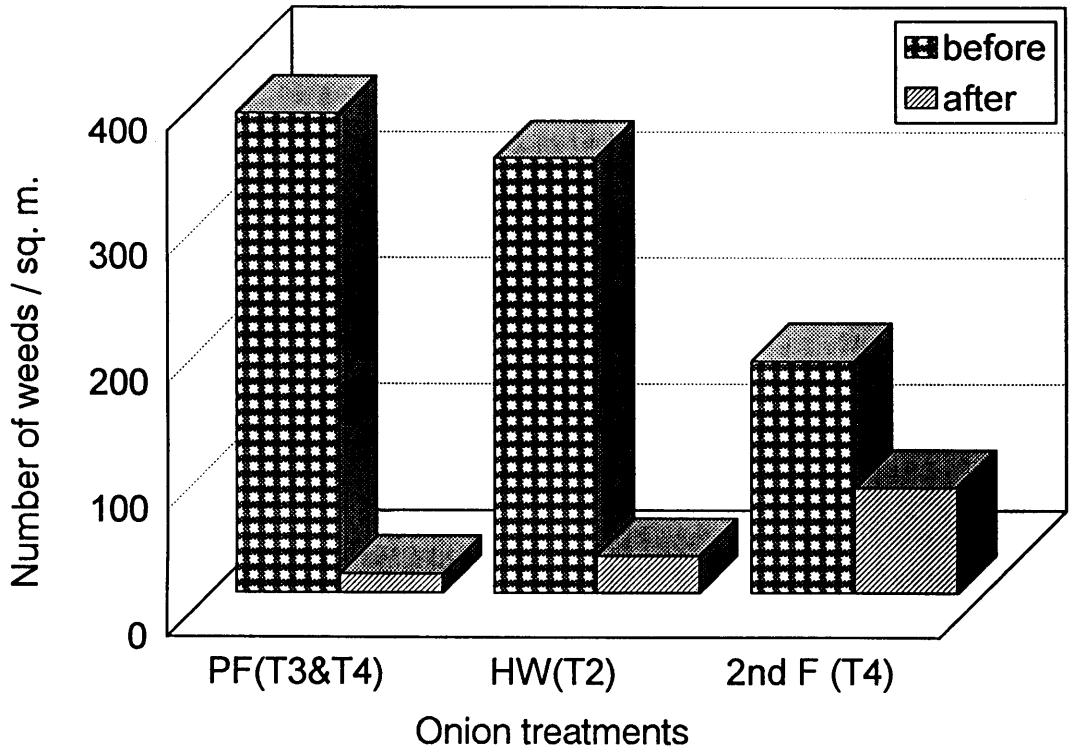

Fig. 1. Efficacy of each treatment on weeds.

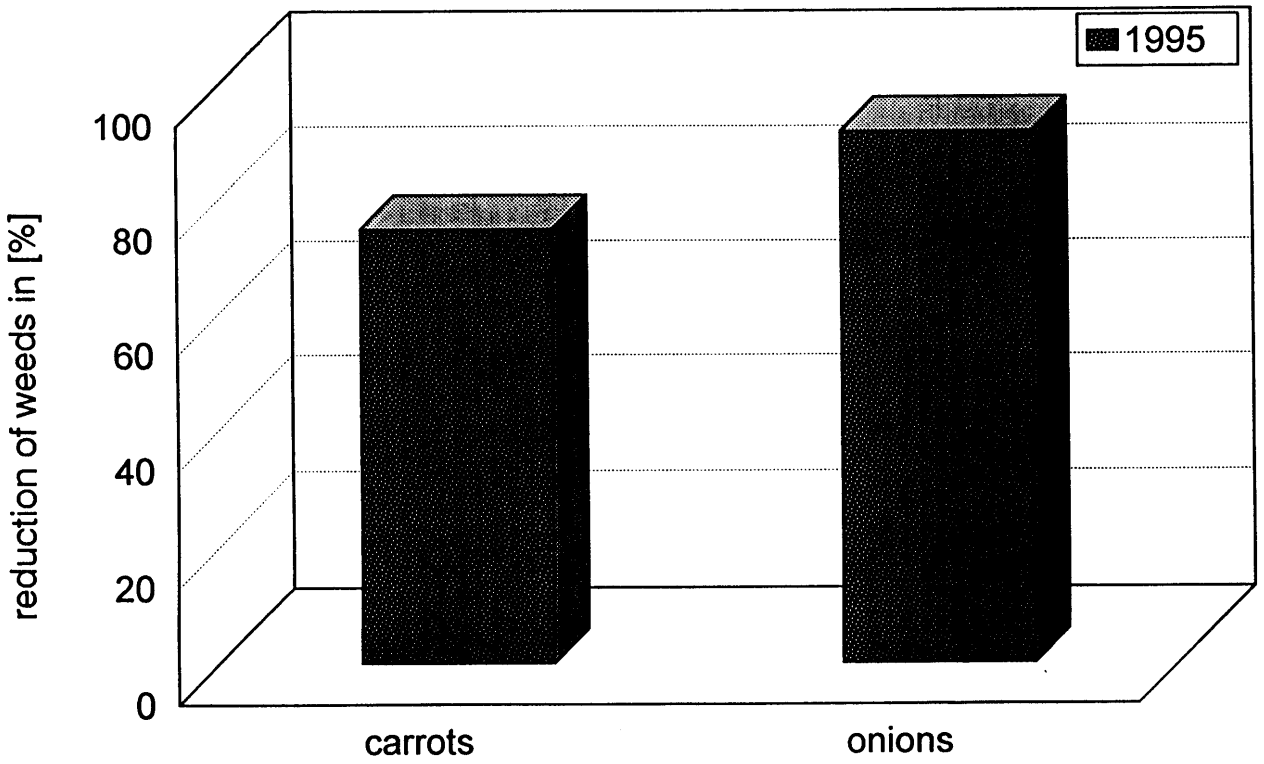

Fig.2. Percentual reduction of weeds in carrots and onions after pre-emergence flame cultivation

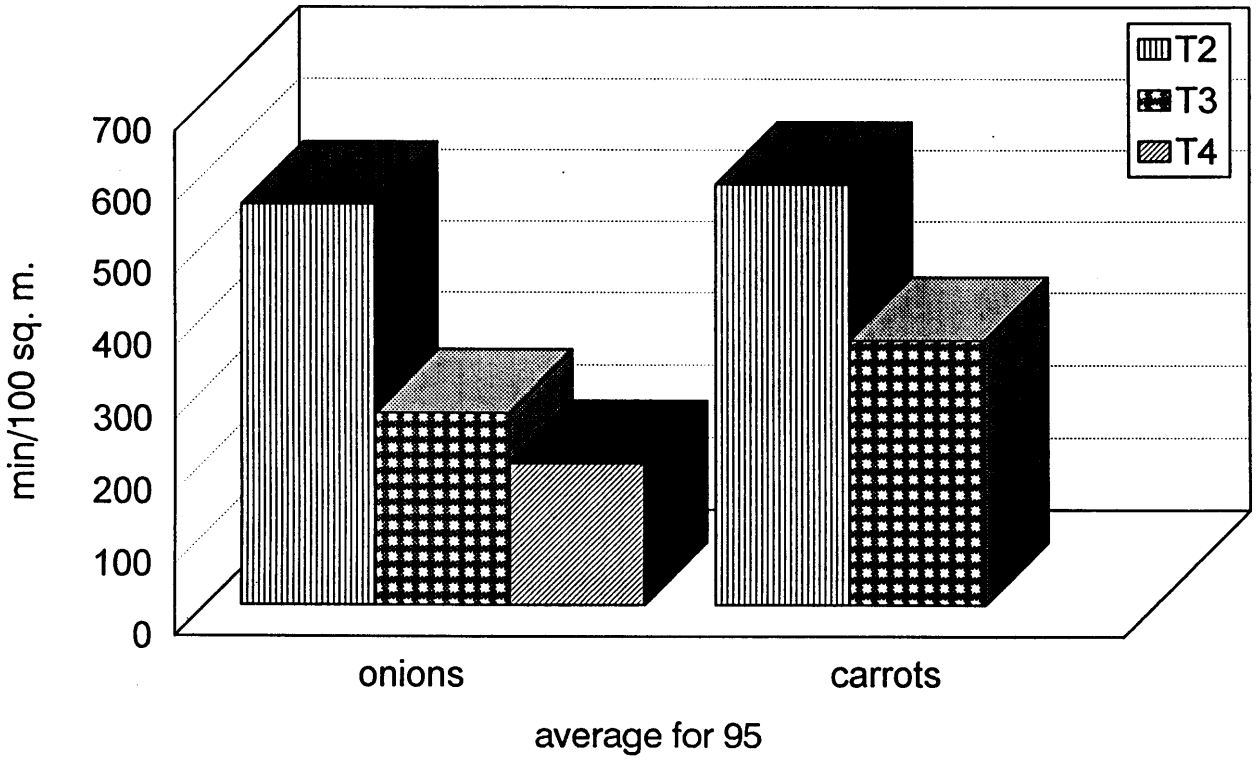

Fig.3. Labour requirement for hand-weeding for onions and carrots.

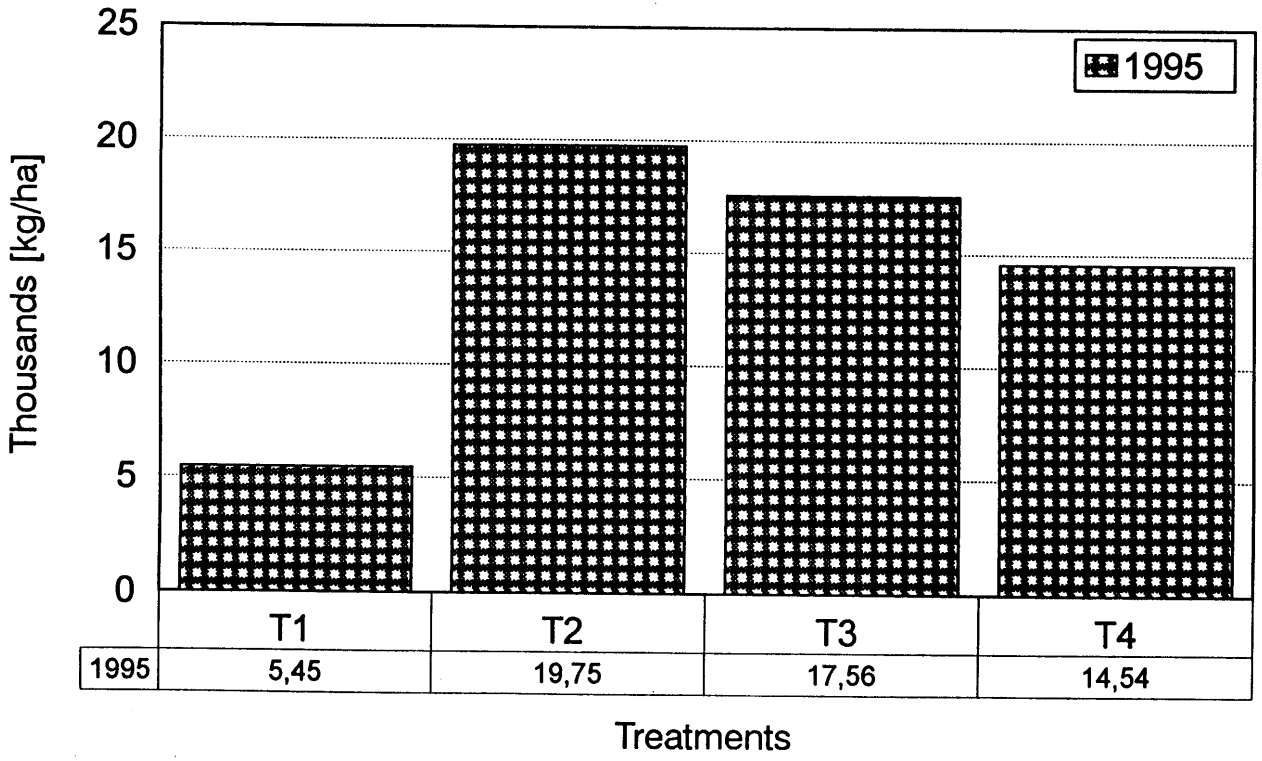

Fig.4. Yields of onions

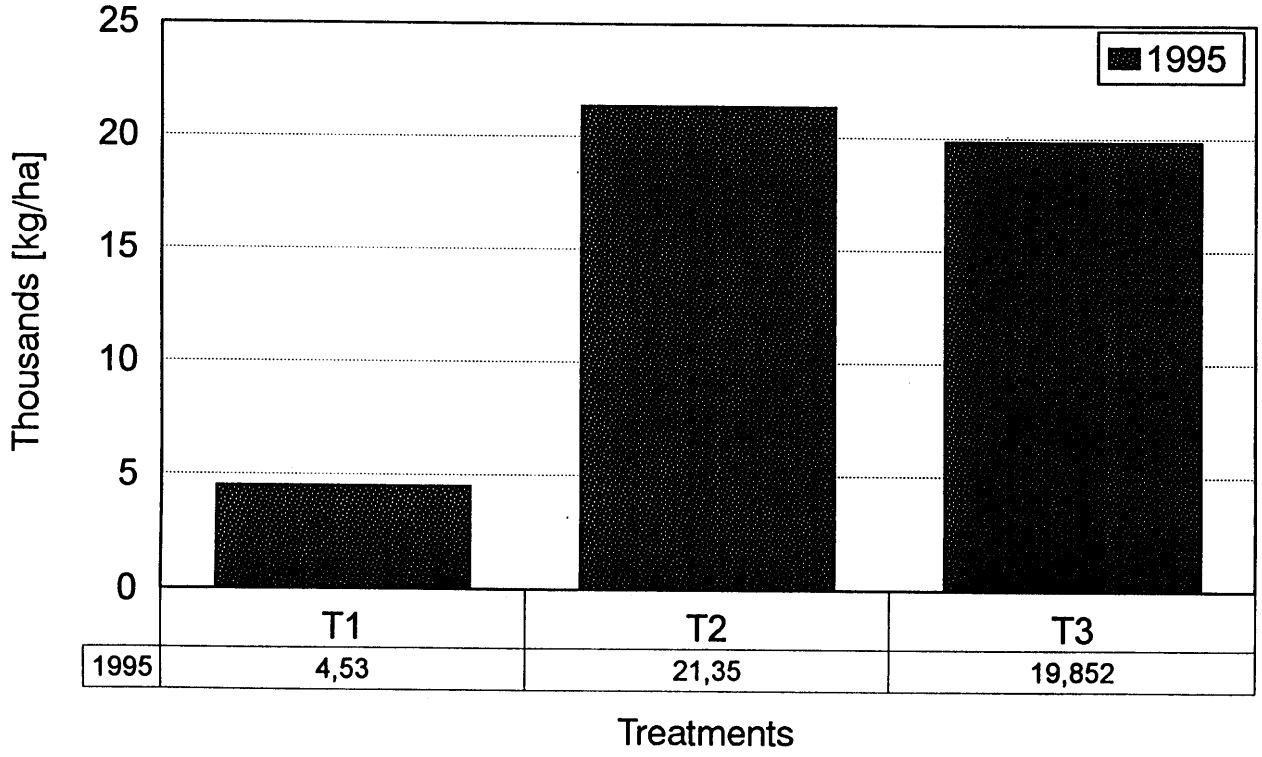

Fig. 5.Yields of carrots