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EFFECTS OF SIMULATED HAIL ON PROCESSING CABBAGE

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EFFECTS OF SIMULATED HAIL ON CABBAGE FOR PROCESSING

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Cabbage is produced in nearly all states of the U.S. and provinces of Canada. The crop used for processing into sauerkraut is produced primarily in Wisconsin, Michigan, Ohio, New York and Ontario. Cabbage used for preparing fresh-cut cole slaw is produced in many states and because of its perishability, it is prepared for more local markets. It is not unusual, however, for the fresh cabbage being shipped long distances to provide off-season produce for any given area.

Cabbage produced for processing into kraut is usually produced under contract with prices and acreage established prior to planting. Slaw cabbage is usually purchased on the open market and is subject to the very wide variations in price common to the fresh market industry.

Cabbage is a gigantic bud in which the growing point is at the center of the plant. It is exposed prior to head formation, but after the head starts to develop the growing point is protected by the large number of tightly-fitted, expanding leaves. If the growing point is damaged or destroyed, the head will not develop any more, although occasionally an axillary bud may develop into a usable head which will mature very late. Damage to the outer leaves after the head starts to develop may cause a slight delay in maturity, but will not completely prevent head formation. Severe injury near maturity will result in considerable trimming at the processing plant which could significantly affect grower returns. Severe injury to fresh market cabbage may result in serious losses because purchasers require several wrapper leaves protecting the inner head.

Most growers of cabbage for processing and especially for fresh market establish their stands in the field by using transplants in New York, Michigan, Wisconsin and Ontario. Ohio growers, however, frequently field seed their crop destined for processing. They over-seed and then thin to a desired stand. The young seedlings are vulnerable to injury from insects, diseases and unfavorable weather and thus, thinning to stand is not usually done until the plants are at least at the 3 or 4 leaf stage and more hardy.

Maturity for harvest is usually based on head size and firmness. Some varieties also begin to burst as maturity approaches, while others hold well and will not burst readily. Processing cabbage is generally harvested once-over by machine. Fresh market cabbage is usually hand cut.

Objectives

1. To develop a description of cabbage growth and development.
2. To determine the influence of several levels of plant injury from simulated hail at different stages of plant development on subsequent yield.

3. To develop tables and charts to predict yield losses based upon severity of hail injury at various stages of plant development.
4. To determine the influence of early stand loss on subsequent yield.

Materials and Methods

General: Field plots were established at the OARDC Vegetable Crops Branch near Fremont, Ohio in 1989, 1990 and 1991. The variety used was Titanic 90, and cultural practices were similar to those used in commercial practice in Ohio. Spacing was 3 ft. between rows and 1.5 ft. within rows. Plot size and treatment replication (4 to 8 reps per treatment) was sufficient to provide statistically separable data. Irrigation was available and used to sustain the plants when water stress occurred.

Hail was simulated by blowing crushed (1989,90) or chunk (1991) ice in a high-speed air stream through a 4-inch tube from above and off vertical at about 45°. Injury was assessed 1 or 2 days after hailing to allow injured leaves to turn brown and/or drop off. The injury was assessed primarily by foliage loss in comparison to non-injured plants. There was, however, some injury to the plant stem when the plants were small. It was also very difficult to defoliate the plants because cabbage leaves are thick and very tough and during later stages, the heads prevented high degrees of defoliation. Young plants were easier to defoliate but considerable ice was required and much more in comparison to more succulent plants like tomato or cucumber.

The plots were harvested when the check plants were mature. The heads were weighed and examined visually for usable quality with non-usable heads discarded.

Hail Injury: Hail treatments were applied at 3 stages of growth: 1) early seedling stage - 4-6 true leaves; 2) cupping stage - center leaves starting to form heads; 3) head fill - heads about half grown. Efforts were to have 3 degrees of injury at these 3 stages: slight = about 25% defoliation; moderate = about 50% defoliation; severe = about 75% defoliation. It was not possible to get much above 50% defoliation at the head fill stage.

Stand Reduction: Field plots were established by field seeding in 1989 and 1990 and thinned to a stand of 18 inches between plants in 30-inch rows when the plants were in the early seedling stage. A few days later after the remaining plants showed they were well established, additional plants were randomly removed to give 90, 75 and 50 percent stands.

Results and Discussion

Plant Development (Staging): There could be numerous stages for this rapidly growing plant. It is nearly impossible to place a time period from one stage to the next because varieties differ greatly in development and environmental factors greatly influence growth rate. The stages proposed are:

1. Cotyledonary stage with only seed leaves present.
2. Early seedling with up to 6 true leaves.

3. Late seedling with 9 to 12 true leaves and the base of the stem still visible from above the plant.
4. Precupping, approximately 13 to 19 leaves. By the end of this stage, the base of the stem and the bases of all leaves are concealed when the plant is viewed from above. The innermost heart leaves are growing upright and are visible without moving any of the surrounding leaves. The central bud is very vulnerable to hail injury at this stage.
5. Cupping, approximately 20 to 26 leaves. The innermost heart leaves are still growing upright and are concealed by the larger, older leaves surrounding them. All visible leaves will later become the frame leaves of the mature plant. Central bud can be relatively easily broken off.
6. Early head formation, approximately 2.5-4 in. diameter head. The inner heart leaves, now quickly developing as a ball-like structure of overlapping leaves, are concealed by the surrounding larger leaves. These leaves do not press tightly against the developing head and will later unfold to become frame leaves.
7. Head fill, approximately half grown. A firm, round head is visible within the wrapper leaves (the 4 outer loose leaves that touch the mature head). The head has not yet fully developed and thus, is not of harvestable size.
8. Mature, approximately 6-12 in. diameter head. No new visible leaf production will occur after the head has attained maximum hardness and size. The head is ready for harvest and may split if not harvested in time.

Hail Injury Effects on Plant Development and Yield: The simulated hail injury as measured by plant defoliation had no influence on total yield when hail occurred at the early seedling stage for all 3 years (Figs. 1 and 2). Injury at later stages had a slightly greater influence on yield, which was in part due to the delay in development as indicated by the reduction in head size (Figs. 3 and 4). The correlation coefficients are quite low from all these data and this becomes quite evident when examining data from the individual years (Figs. 5-16). Nevertheless, the trends are certainly evident.

One factor which these data do not show is the increased amount of trimming which would be necessary on heads which were injured during mid-head formation. Further, we did not record the amount of trim-time needed. There is little doubt, however, that as severity of injury increased after head formation, the amount of trimming to remove the injured leaves would be significant.

Another factor that needs to be mentioned is that it was very difficult to defoliate the older plants and with the lack of higher levels of defoliation the calculations above about 50% injury for the head fill stage are very speculative.

Calculations of Predicted Yield Loss Based Upon Defoliation: Stages up to Stage 6, early head formation, there probably is little effect of hail injury on plant yield. If the growing point is destroyed, the calculations based upon stand

can be used.

After Stage 6, the following formula can be used with up to 60% defoliation:

$$Y^* = 23.848 - (0.1069.x^{**})$$

*Y = tons per acre predicted from regression formula

**x = percentage plant defoliation observed

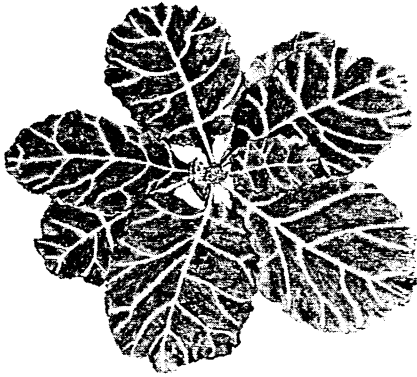
Influence of Plant Stand on Yield: Results from seedling removed to give 50, 75, 90 and 100 percent stands revealed that a reduction in plant stand causes a reduction in yield (Fig. 17). Although there was some mitigation of loss of plants by increase in head size from plants adjacent to the missing plants, this was not sufficient to make up for the loss of individual heads.

There is little doubt that cabbage crops should have as near to 100% stand as possible because each plant forms one and only one head. Any loss in stand or injury to the growing point of plants will result in harvestable yield loss.

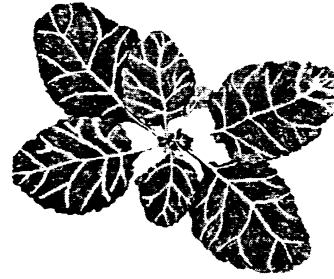
STAGES OF CABBAGE PLANT DEVELOPMENT

Stage 1: Cotyledonary stage with only seed leaves present.

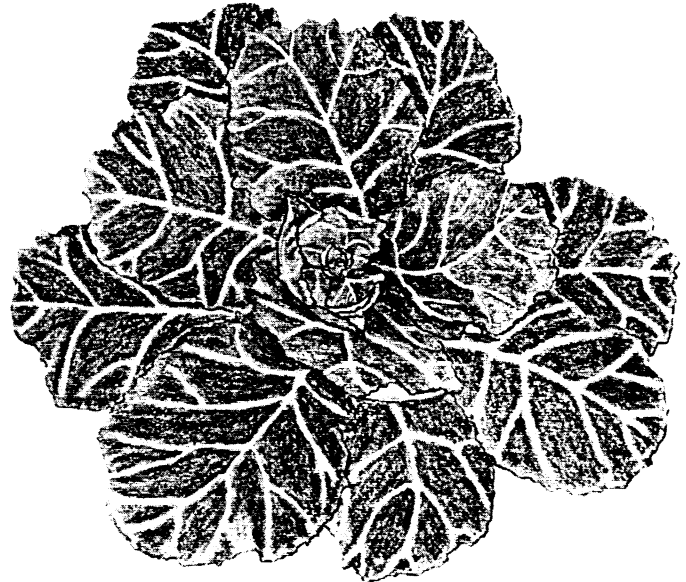
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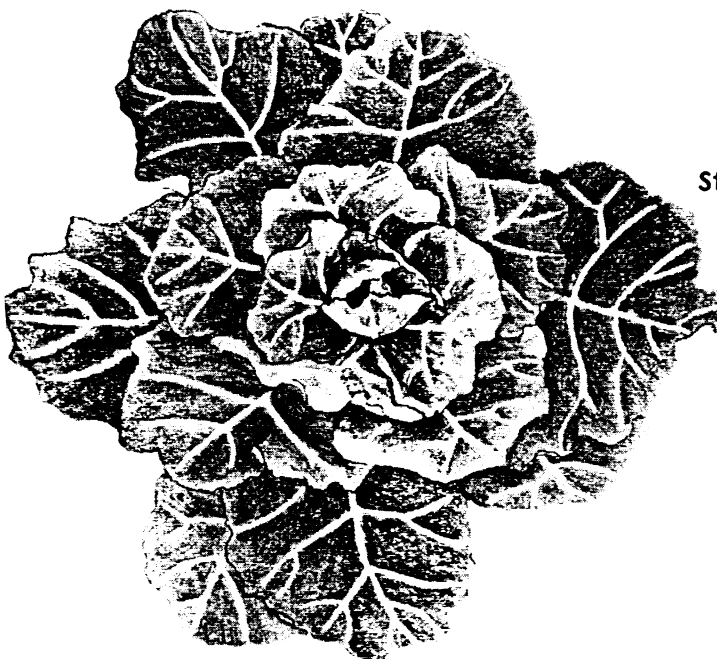
Stage 2: Early seedling with up to 6 true leaves.



Stage 3: Late seedling with 9 to 12 true leaves and the base of the stem still visible from above the plant.



Stage 4: Precupping, approximately 13 to 19 leaves. By the end of this stage, the base of the stem and the bases of all leaves are concealed when the plant is viewed from above. The innermost heart leaves are growing upright and are visible without moving any of the surrounding leaves. The central bud is very vulnerable to hail injury at this stage.



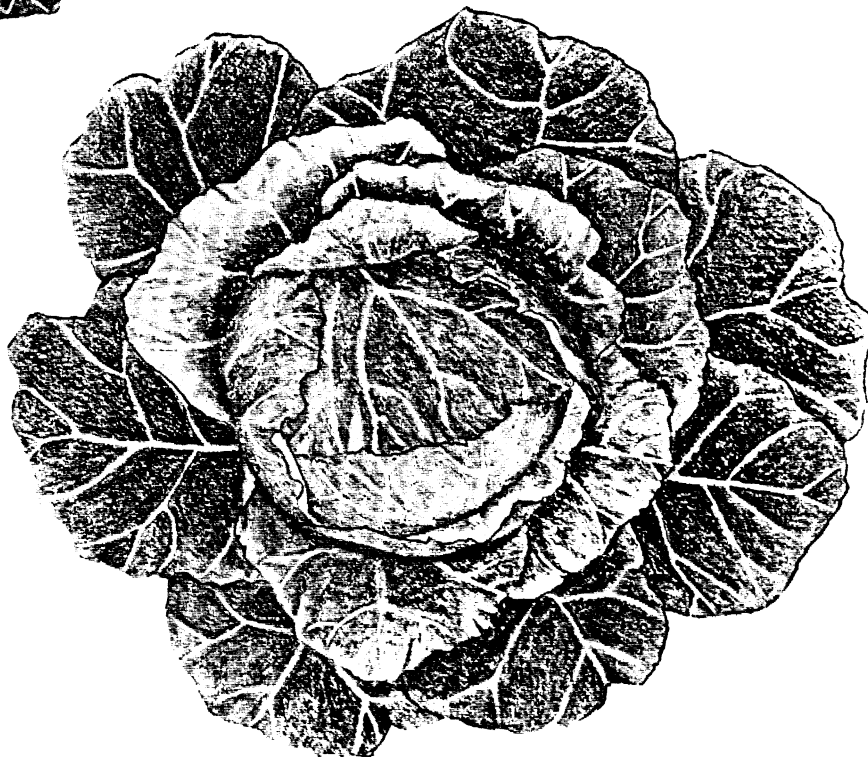
Stage 5: Cupping, approximately 20 to 26 leaves. The innermost heart leaves are still growing upright and are concealed by the larger, older leaves surrounding them. All visible leaves will later become the frame leaves of the mature plant. Central bud can be relatively easily broken off.

Stage 6: Early head formation, approximately 2.5-4 in. diameter head. The inner heart leaves, now quickly developing as a ball-like structure of overlapping leaves, are concealed by the surrounding larger leaves. These leaves do not press tightly against the developing head and will later unfold to become frame leaves.

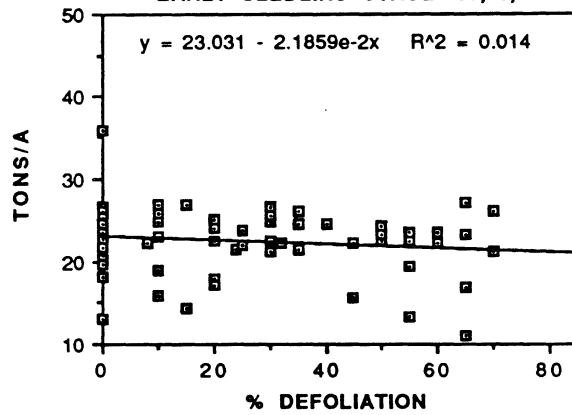


Stage 7: Head fill, approximately half grown. A firm, round head is visible within the wrapper leaves (the 4 outer loose leaves that touch the mature head). The head has not yet fully developed and thus, is not of harvestable size.

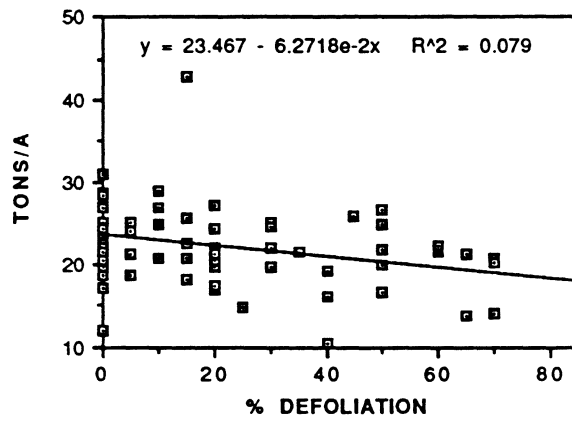
Stage 8: Mature, approximately 6-12 in. diameter head. No new visible leaf production will occur after the head has attained maximum hardness and size. The head is ready for harvest and may split if not harvested in time.



HAIL EFFECTS ON TOTAL YIELD OF CABBAGE
EARLY SEEDLING STAGE- 89,90,91



HAIL EFFECTS ON TOTAL YIELD OF CABBAGE
CUPPING STAGE-89,90,91



HAIL EFFECTS ON TOTAL YIELD OF CABBAGE
HEAD FILL STAGE- 89,90,91

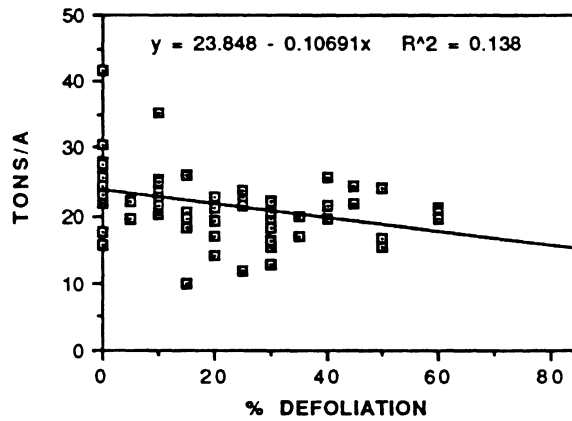
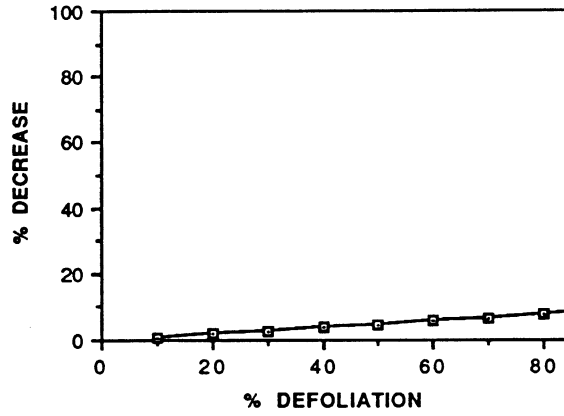
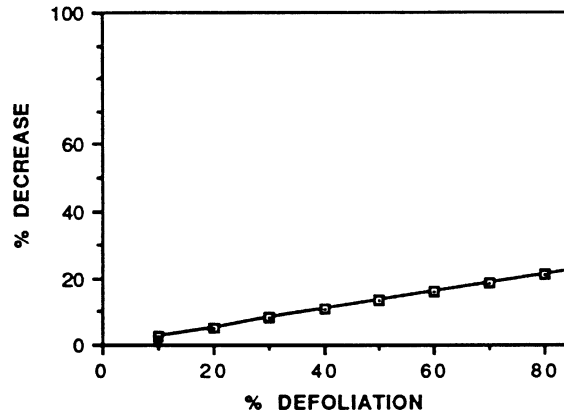


Fig. 1. Influence of simulated hail treated at 3 stages of plant development on yield of processing cabbage, 1989, 1990 and 1991.

HAIL EFFECTS ON TOTAL YIELD OF CABBAGE
EARLY SEEDLING STAGE- 89,90,91



HAIL EFFECTS ON TOTAL YIELD OF CABBAGE
CUPPING STAGE- 89,90,91



HAIL EFFECTS ON TOTAL YIELD OF CABBAGE
HEAD FILL STAGE- 89,90,91

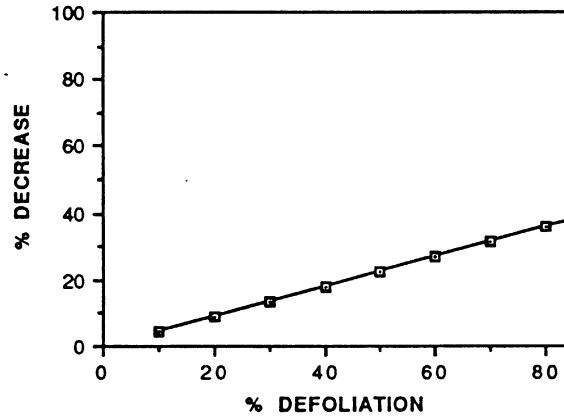
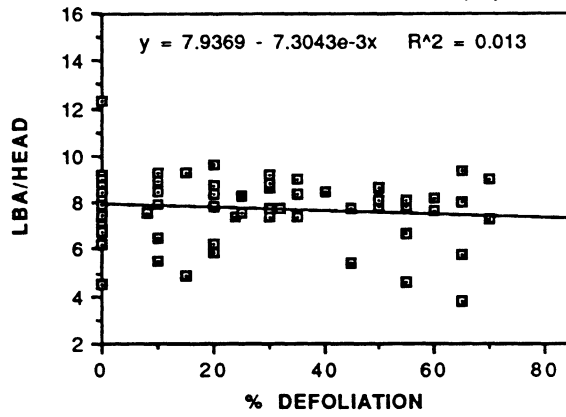
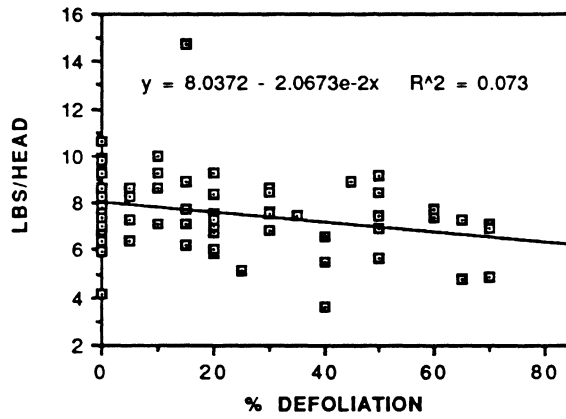


Fig. 2. Influence of simulated hail treated at 3 stages of plant development on decrease in yield or processing cabbage, 1989, 1990 and 1991.

HAIL EFFECTS ON HEAD SIZE OF CABBAGE
EARLY SEEDLING STAGE 89,90,91



HAIL EFFECTS ON HEAD SIZE OF CABBAGE
CUPPING STAGE- 89,90,91



HAIL EFFECTS ON HEAD SIZE OF CABBAGE
HEAD FILL STAGE- 89,90,91

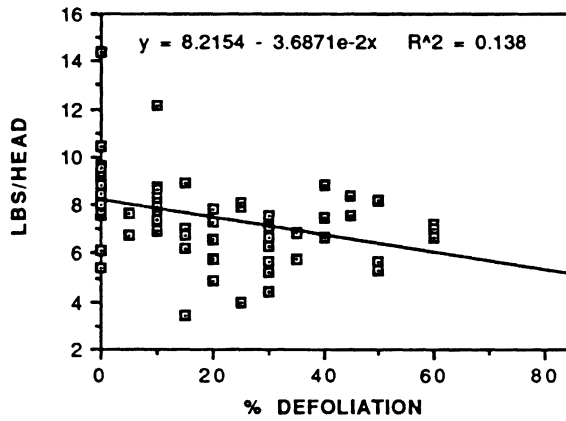
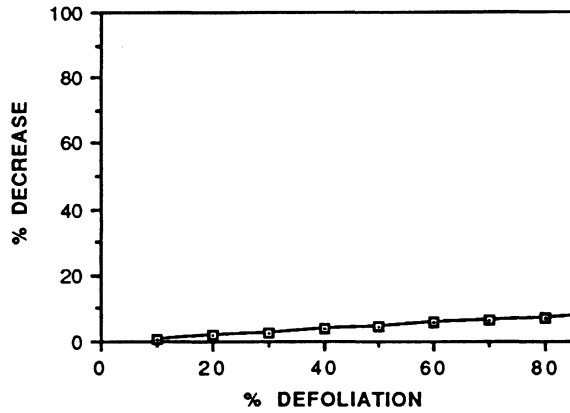
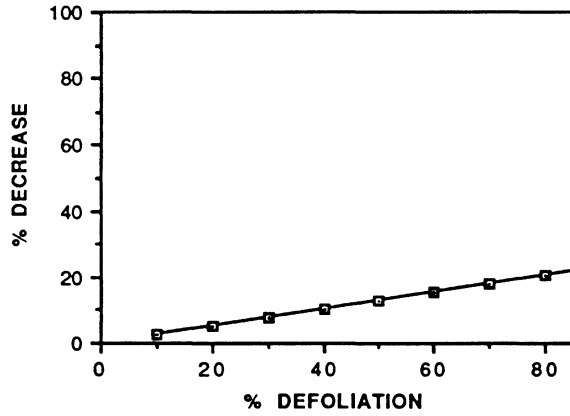


Fig. 3. Influence of simulated hail treated at 3 stages of plant development on head size of processing cabbage, 1989, 1990, 1991.

HAIL EFFECTS ON HEAD SIZE OF CABBAGE
EARLY SEEDLING STAGE- 89,90,91



HAIL EFFECTS ON HEAD SIZE OF CABBAGE
CUPPING STAGE- 89,90,91



HAIL EFFECTS ON HEAD SIZE OF CABBAGE
HEAD FILL STAGE- 89,90,91

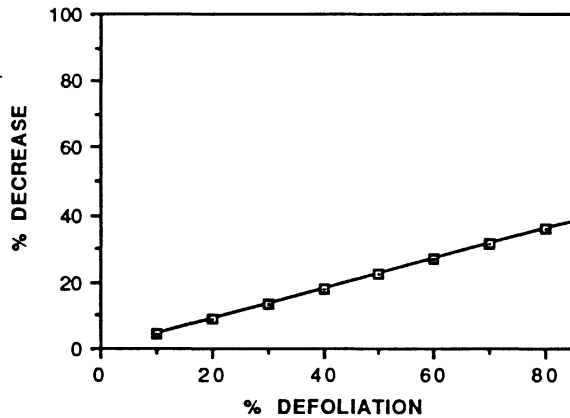
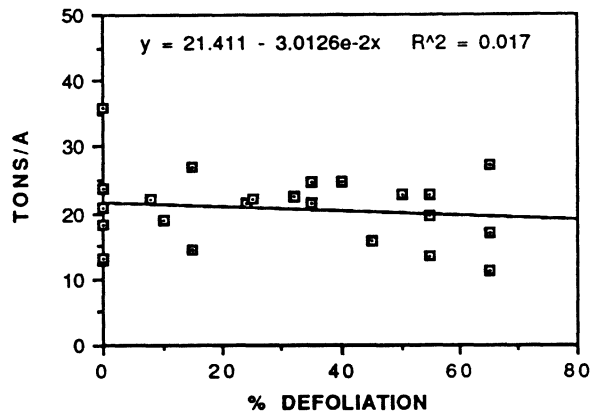
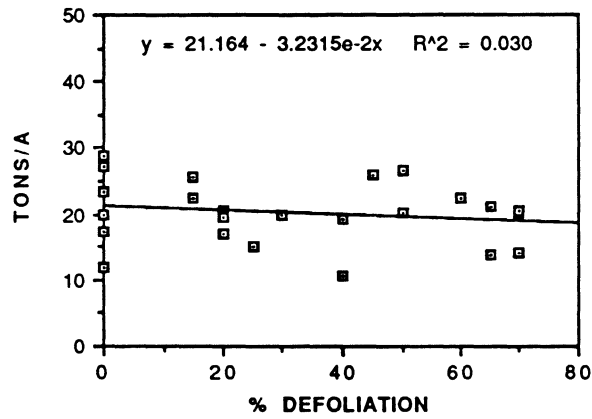


Fig. 4. Influence of simulated hail treated at 3 stages of plant development on decrease in head size of processing cabbage, 1989, 1990, 1991.

HAIL EFFECTS ON TOTAL YIELD OF CABBAGE
EARLY SEEDLING STAGE-1989



HAIL EFFECTS ON TOTAL YIELD OF CABBAGE
CUPPING STAGE-1989



HAIL EFFECTS ON TOTAL YIELD OF CABBAGE
HEAD FILL STAGE-1989

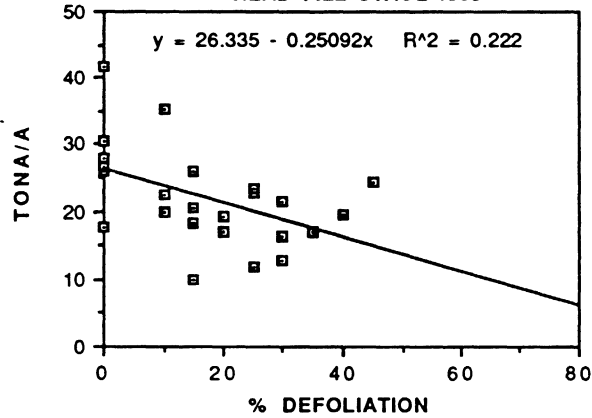


Fig. 5. Influence of simulated hail treated at 3 stages of plant development on yield of processing cabbage, 1989.

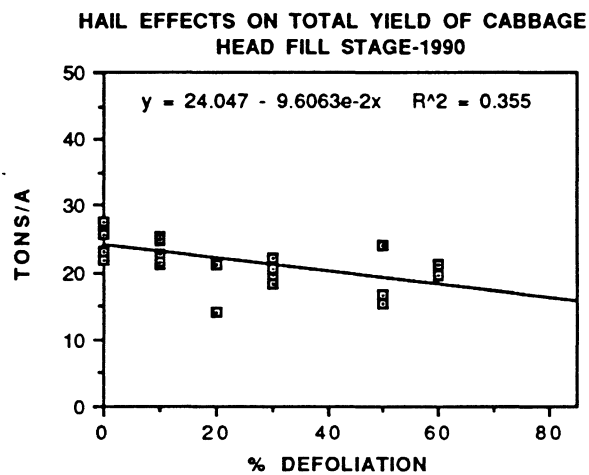
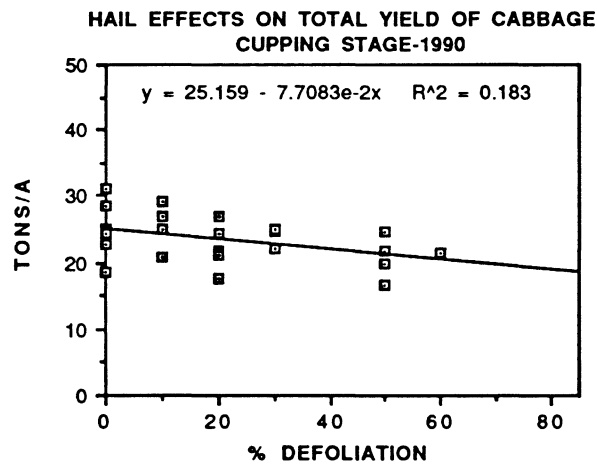
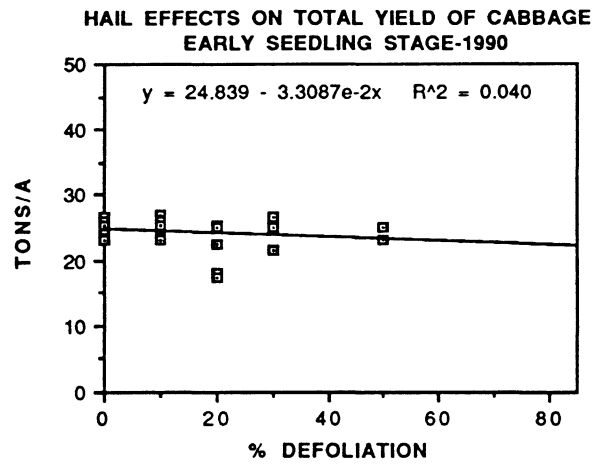
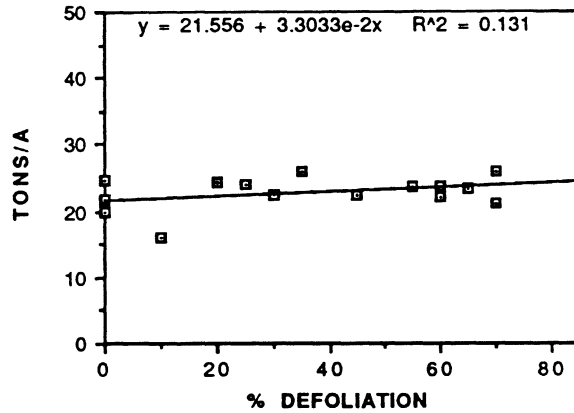
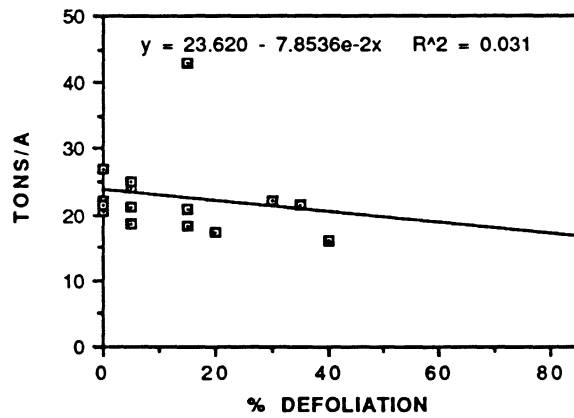


Fig. 6. Influence of simulated hail treated at 3 stages of plant development on yield of processing cabbage, 1990.

HAIL EFFECTS ON TOTAL YIELD OF CABBAGE
EARLY SEEDLING STAGE-1991



HAIL EFFECTS ON TOTAL YIELD OF CABBAGE
CUPPING STAGE -1991



HAIL EFFECTS ON TOTAL YIELD OF CABBAGE
HEAD FILL STAGE -1991

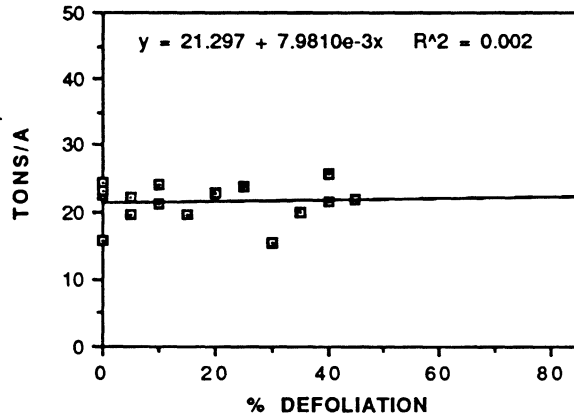


Fig. 7. Influence of simulated hail treated at 3 stages of plant development on yield of processing cabbage, 1991.

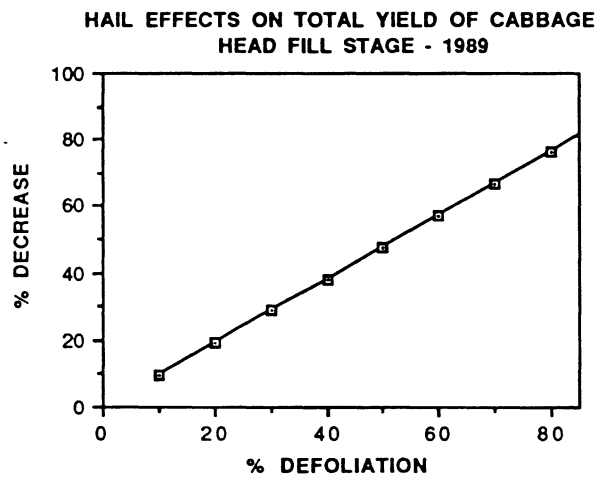
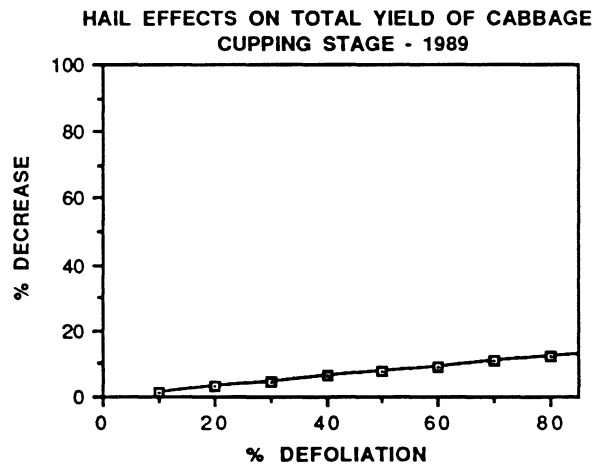
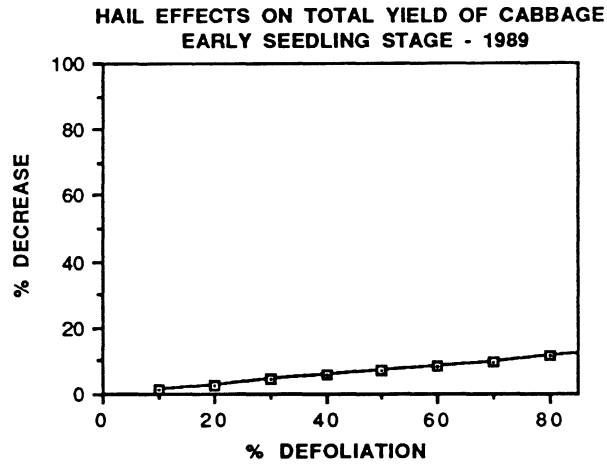


Fig. 8. Influence of simulated hail treated at 3 stages of plant development on decrease in yield of processing cabbage, 1989.

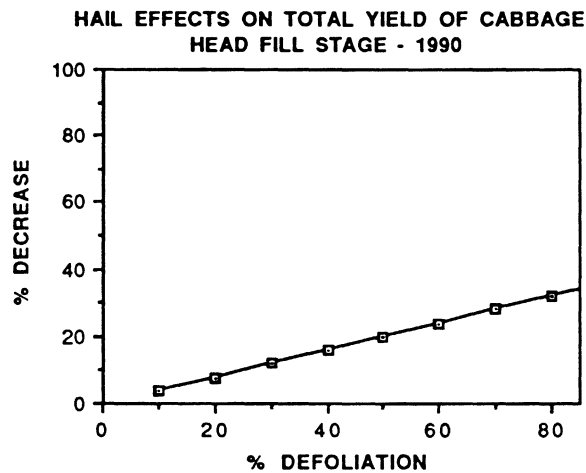
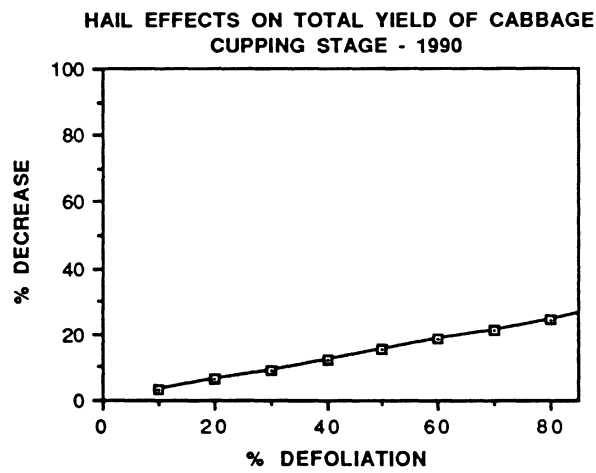
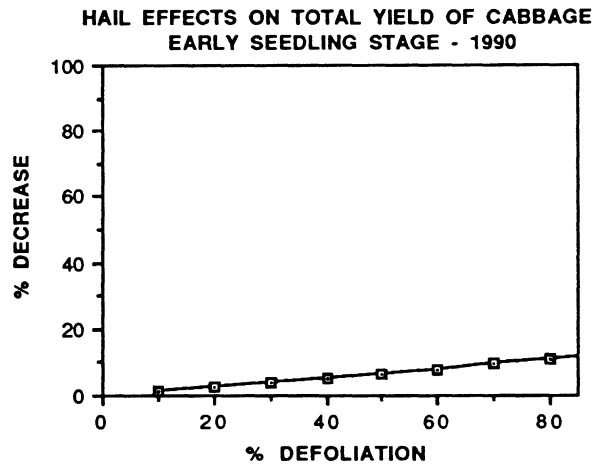
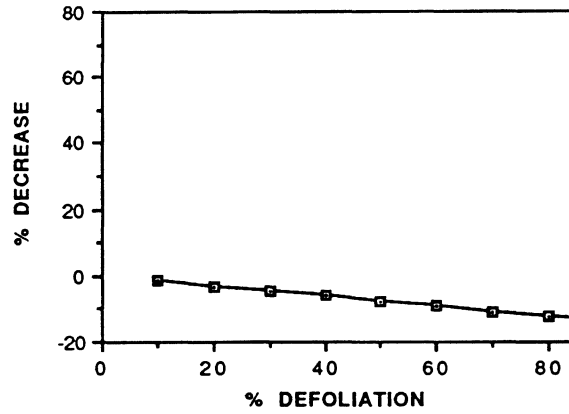
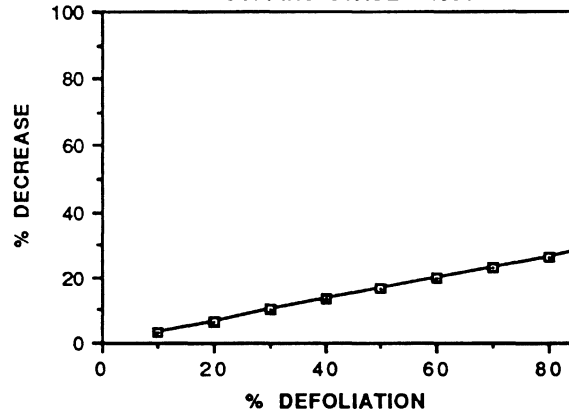


Fig. 9. Influence of simulated hail treated at 3 stages of plant development on decrease in yield of processing cabbage, 1990.

HAIL EFFECTS ON TOTAL YIELD OF CABBAGE
EARLY SEEDLING STAGE - 1991



HAIL EFFECTS ON TOTAL YIELD OF CABBAGE
CUPPING STAGE - 1991



HAIL EFFECTS ON TOTAL YIELD OF CABBAGE
HEAD FILL STAGE - 1991

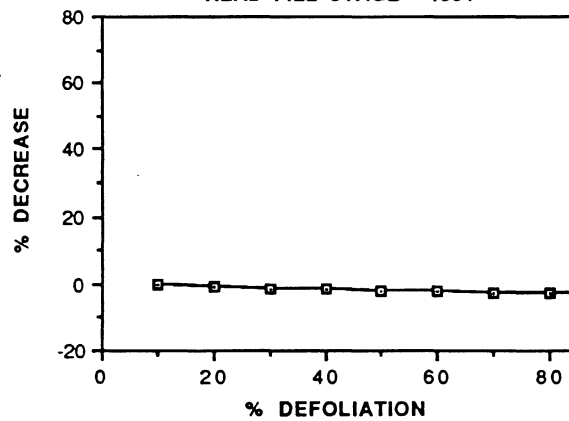
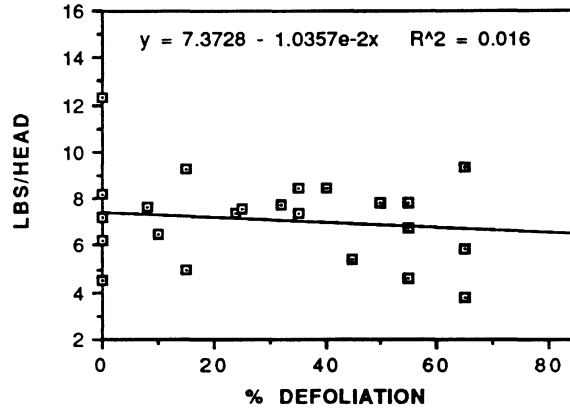
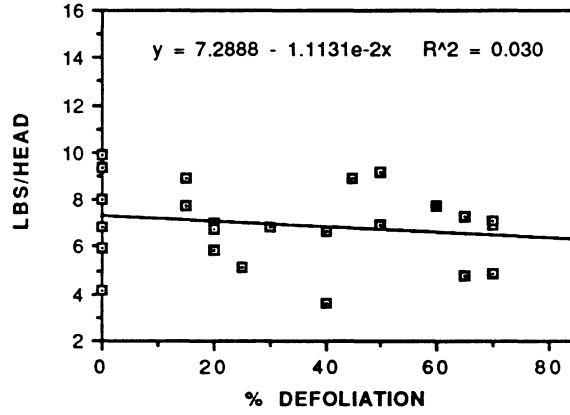


Fig. 10. Influence of simulated hail treated at 3 stages of plant development on decrease in yield of processing cabbage, 1991.

HAIL EFFECTS ON HEAD SIZE OF CABBAGE
EARLY SEEDLING STAGE-1989



HAIL EFFECTS ON HEAD SIZE OF CABBAGE
CUPPING STAGE-1989



HAIL EFFECTS ON HEAD SIZE OF CABBAGE
HEAD FILL STAGE - 1989

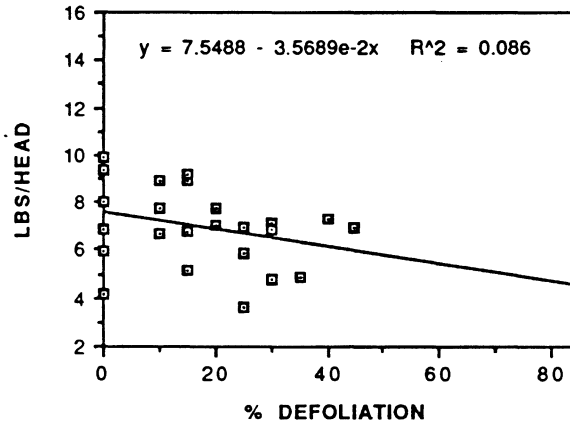
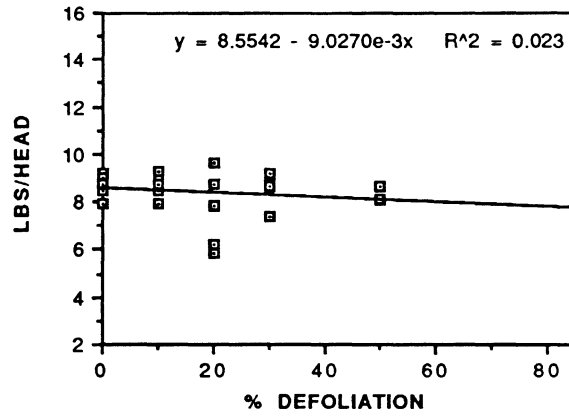
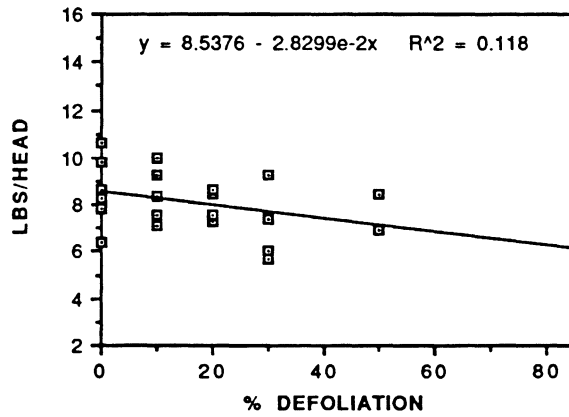


Fig. 11. Influence of simulated hail treated at 3 stages of plant development on head size of processing cabbage, 1989.

HAIL EFFECTS ON HEAD SIZE OF CABBAGE
EARLY SEEDLING STAGE-1990



HAIL EFFECTS ON HEAD SIZE OF CABBAGE
CUPPING STAGE-1990



HAIL EFFECTS ON HEAD SIZE OF CABBAGE
HEAD FILL STAGE-1990

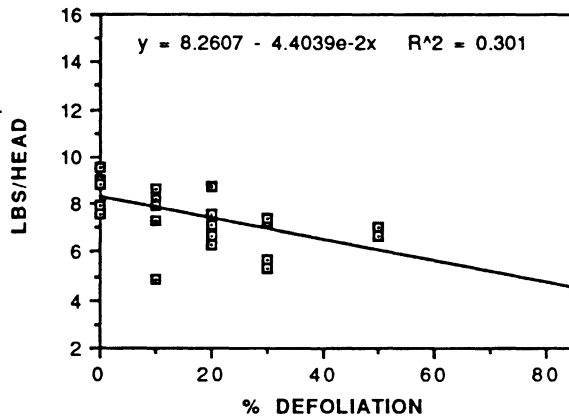
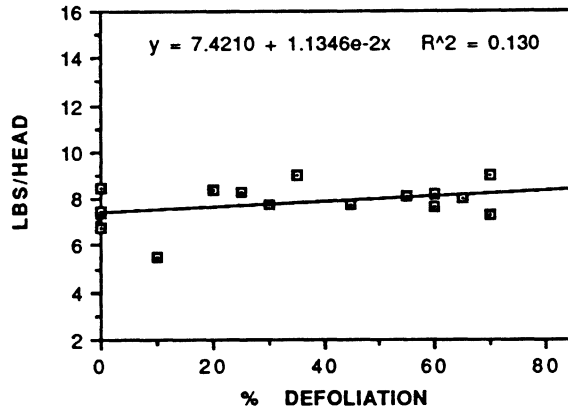
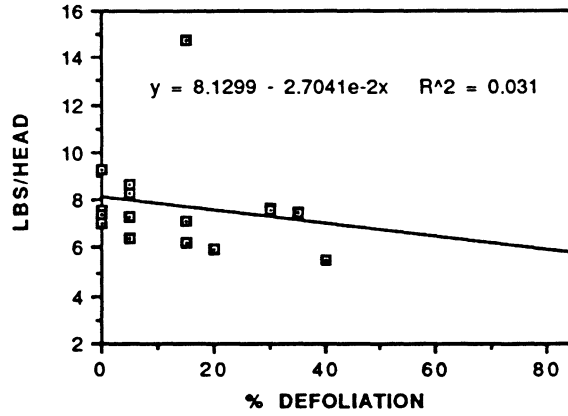


Fig. 12. Influence of simulated hail treated at 3 stages of plant development on head size of processing cabbage, 1990.

HAIL EFFECTS ON HEAD SIZE OF CABBAGE
EARLY SEEDLING STAGE-1991



HAIL EFFECTS ON HEAD SIZE OF CABBAGE
CUPPING STAGE -1991



HAIL EFFECTS ON HEAD SIZE OF CABBAGE
HEAD FILL STAGE-1991

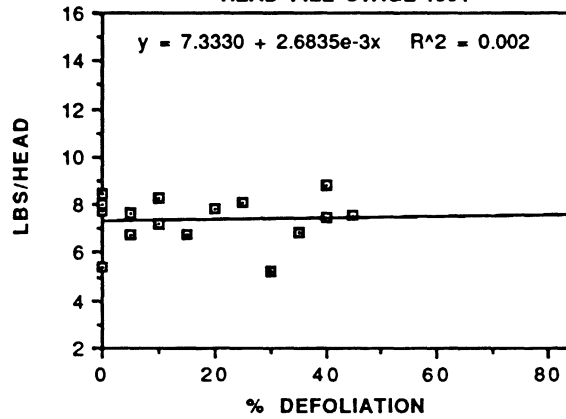


Fig. 13. Influence of simulated hail treated at 3 stages of plant development on head size of processing cabbage, 1991.

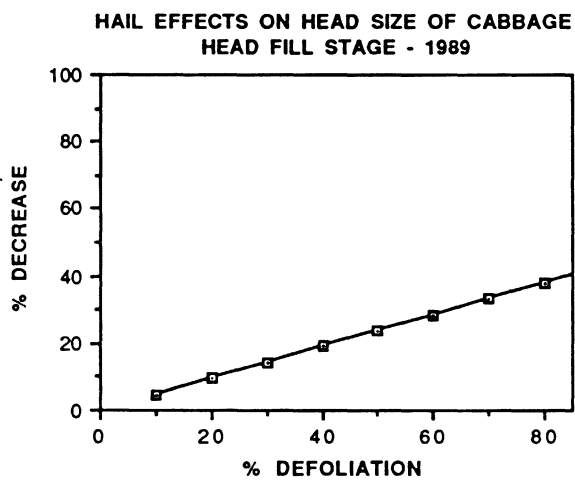
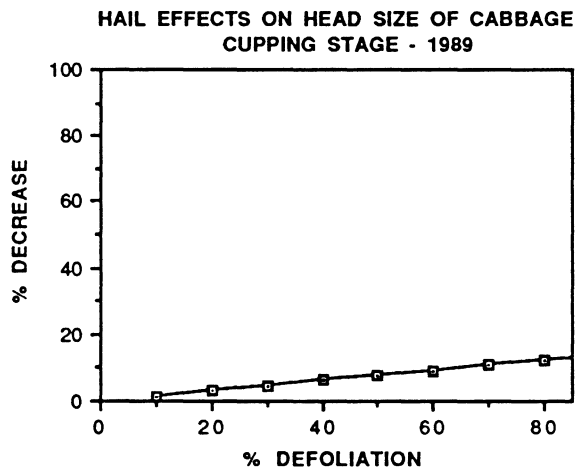
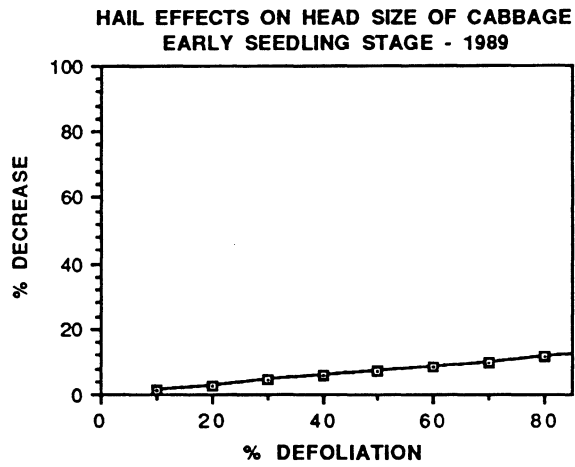


Fig. 14. Influence of simulated hail treated at 3 stages of plant development on decrease in head size of processing cabbage, 1989.

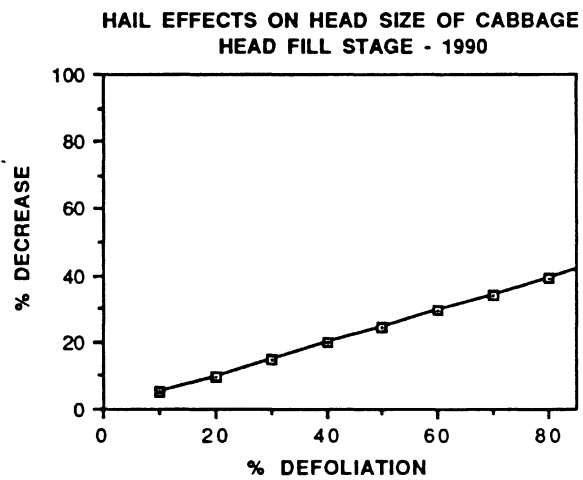
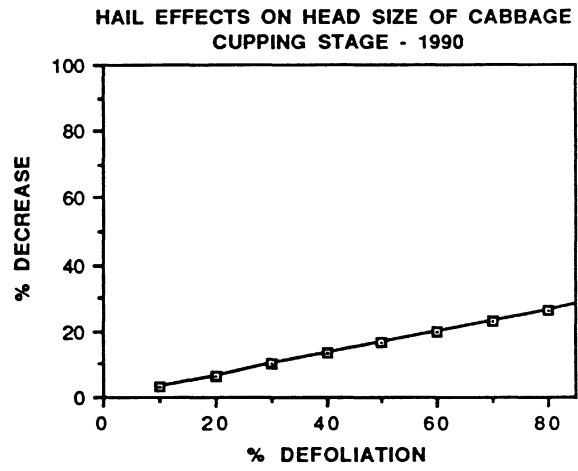
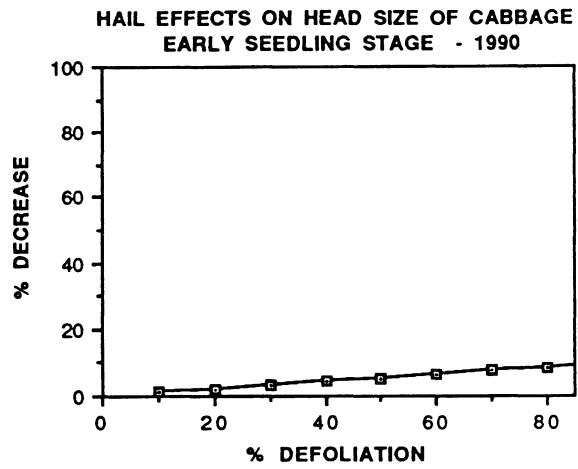


Fig. 15. Influence of simulated hail treated at 3 stages of plant development on decrease in head size of processing cabbage, 1990.

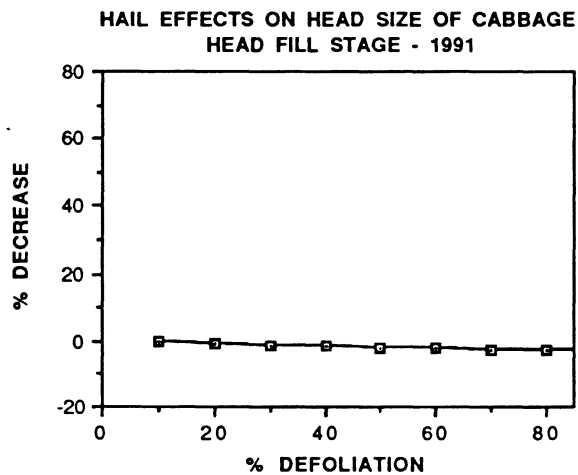
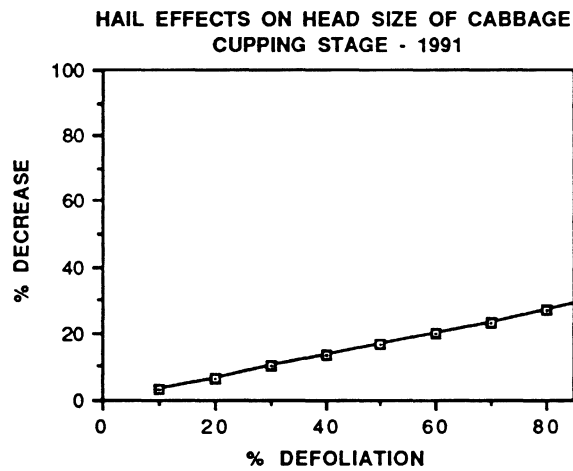
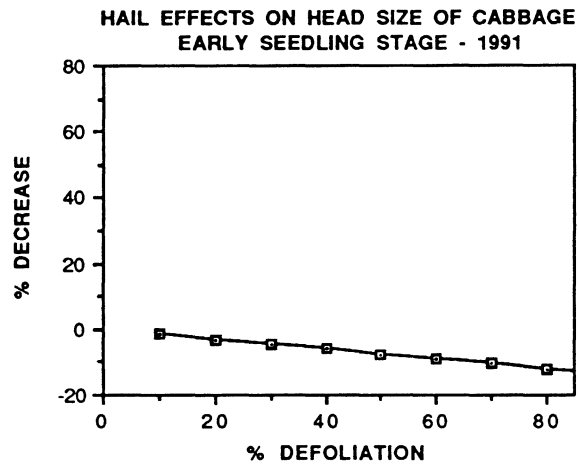
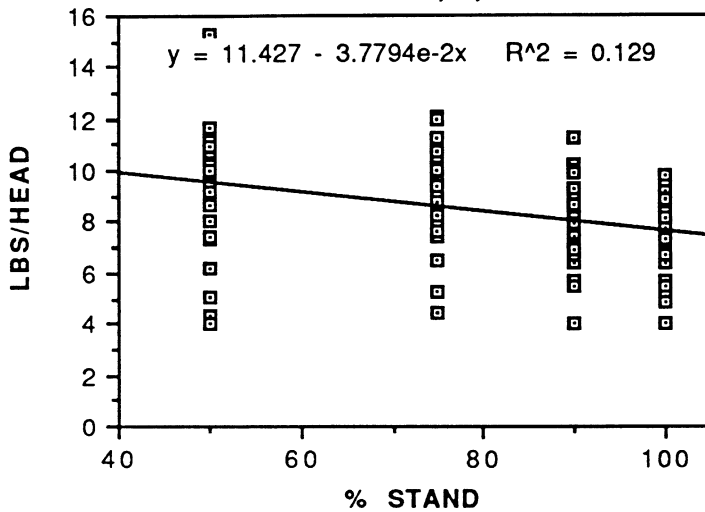


Fig. 16. Influence of simulated hail treated at 3 stages of plant development on decrease in head size of processing cabbage, 1991.

EFFECT OF PLANT STAND ON HEAD SIZE OF CABBAGE

1989,90,91



EFFECT OF PLANT STAND ON TOTAL YIELD OF CABBAGE

1989,90,91

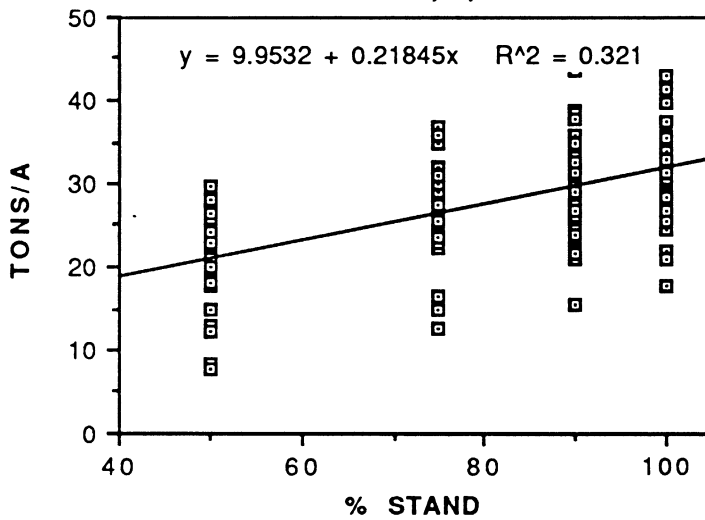


Fig. 17. Influence of plant stand on yield of processing cabbage, 1989, 1990, 1991.

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