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Asparagus: A study of tiprot, its physiological and genetic basis

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Summary

Tiprot is a major factor limiting the storage life of asparagus. It is a softening of the spear tip which develops into complete tissue disintegration. Tiprot occurs particularly after periods of storage. Although it appears to be a rot tiprot is not associated with any pathogen and is caused by changes in the physiology of the spear tip.

When we tested individual plants for tiprot development we found a very wide range in susceptibility to the disorder. These differences were fairly consistent over three years of monitoring. Tests with a large number of cultivars showed a wide range of susceptibility. The genetic makeup of the plant is probably affecting its susceptibility to tiprot. Selection and breeding may be a useful method for reducing the susceptibility of asparagus to tiprot.

Irrigation treatments had little, if any, effect on tiprot development. There was a slight tendency for irrigation during the fern stage to reduce the level of tiprot but this effect was small compared to the effect of cultivar. Jersey Giant had less tiprot than UC157.

Harvest time had by far the greatest effect on tiprot in these experiments. In early October the incidence of tiprot was low, but by early November tiprot occurred in over 90% of spears after the standard storage and shelf-period. Some major physiological change must occur over this period to predispose the spears to get tiprot.

Plants identified as susceptible to tiprot had higher levels of protein, lower soluble carbohydrates and higher ammonia in spear tips at harvest than plants which were less susceptible. Ammonia accumulated sooner after harvest in spear tips from susceptible plants than from less susceptible plants. We conclude from these results that spears with low soluble carbohydrate at harvest switch to protein as a metabolic energy source sooner than spears with high carbohydrate levels. Consequently ammonia accumulation occurs sooner, resulting in tissue damage and secondary infection.

Further work is needed to verify the toxicity of ammonia to asparagus tissue, and to discover what influences soluble carbohydrate levels in spear tips.

Introduction

Tiprot in asparagus is a major single factor limiting storage life of asparagus. Symptoms of the disorder include softening of the spear tip, developing into complete tissue disintegration of the upper 20-30 mm of the spear. Tiprot develops particularly after periods of storage.

Although it appears to be a rot, various attempts to identify a pathogen have revealed only secondary saprophytes in the affected tissue. Efforts to control the disorder using fungicides have been unsuccessful (Carpenter et al. 1988).

We think that tiprot is a physiological disorder. Spears lose their substrate supply at harvest, and rapidly use up available sugars particularly in the active tip region (Lill et al 1990). The tissue then degrades protein as an energy source, but after a period is unable to detoxify the released amino groups. These accumulate as ammonium possibly to toxic levels (King et al. 1990). Severe membrane damage and leakage of cell contents have been observed around the time of ammonia accumulation. Saprophytic micro-organisms can then grow readily on the damaged tissue.

If the disorder has a physiological basis then it may be influenced by plant genotype or by the physical environment of the asparagus plant. Early observations at Levin have demonstrated variation in susceptibility to tiprot between plants in an old Mary Washington stand. Studies at Lincoln on asparagus flavour have indicated the development of 'bitterness' in some breeding lines and not in others. This flavour characteristic seemed to be affected by local weather patterns, being accentuated in hot dry conditions. Tiprot is also more prevalent as the season progresses, either because of warmer weather conditions or because of depletion of reserves in the crown.

This study was aimed at establishing whether tiprot has a genetic basis and whether it is influenced by the crop environment, and investigating physiological factors related to the disorder.

Materials and Methods

1. *Variation between plants.* Four hundred plants in an 8 year old bed of cv. Mary Washington 500 were identified and harvested twice weekly for eight weeks in 1988. Spears were labelled with the plant code, trimmed, and stored for 4 weeks at 0°C. After storage the spears were held at 20°C and assessed for tiprot after 0, 3 and 5 days. Spears with any softening of the tip when pressed gently with a finger were classed as having tiprot.

   At the end of the 1988 season three groups, each with 11 plants, were selected depending on the amount of tiprot observed. These groups were good, medium, and inferior with respect to resistance to tiprot and were monitored for tiprot development during the 1989 and 1990 seasons using the same test as in 1988.

2. *Variation between cultivars.* Asparagus from two trials at Massey University with 11 and 41 cultivars respectively were harvested on 4 occasions during the 1990 season and tested for development of tiprot using the storage test described above. The random layout of these trials should avoid the problems of position in the field which affect conclusions drawn from tests using individual plants (above).

3. *Irrigation management.* Samples of spears were taken on 4 occasions from an irrigation trial at Massey University for storage and assessment of tiprot. Two cultivars (UC157 and Jersey Giant) received either irrigation or no irrigation during either the spear stage or the fern stage in a 2x2x2 factorial design.

4. *Physiological factors in tiprot.* Three groups of Mary Washington 500 plants ranging in resistance to tiprot from good to inferior were selected (see 1 above). Spears were harvested as available during the season and tip sections (30 mm) analysed for protein and soluble carbohydrate content at harvest, and accumulation of ammonia during 72 h at 20°C.

Results and Discussion

1. *Variation between plants.* Huge variation was observed between plants in tiprot development in 1988, ranging from 11% to 100%. Tiprot development occurred primarily during storage, with a rather smaller number of spears developing the symptoms during the shelf period at 20°C (55%, 60%, and 69% after 0, 3, and 5 days at 20°C respectively). Tiprot incidence was around 60% in the first picks (mid October) but jumped sharply to nearly 90% in early November (Fig 1). It increased slowly thereafter with approx. 95% of spears harvested at the end of the season developing tiprot.

   Using data collected during 1988, we selected 11 plants with low levels of tiprot, 11 with high levels, and 11 with intermediate levels. These groups of plants were monitored again in 1989 and 1990. Tiprot in the good group increased appreciably in 1989 but the ranking of the three groups remained consistent over the three years (Fig 2). In 1990 there was little difference between the good and medium groups, but these two always had much less tiprot than the inferior group.

   These results suggest that susceptibility to tiprot is affected by the genetics of the plant and may therefore be a useful character to use when selecting plant material in breeding and plant improvement programmes. This experiment is equivocal, though, and requires demonstration of retention of the character through vegetative propagation of the plants. It is possible that the susceptibility to tiprot was associated in some way with the position of the plant in the field.

2. *Variation between cultivars.* Plant material collected from around the world is being grown at Massey in two cultivar trials. Tiprot susceptibility of these cultivars varied considerably, ranging from 51% to 100% at the end of the 5 day shelf-period (Tables 1 and 2). There was no significant association of tiprot susceptibility with country of origin.

   Tiprot increased dramatically in later harvests, confirming previous observations (Table 3). This effect occurred across all cultivars, and exceeded the effect of the cultivars themselves.

   Differences in susceptibility to tiprot between cultivars support the notion that plant genotype is involved in determining the development of this disorder. The random layout of these experiments in the field will have eliminated the possibility that site effects are influencing results.

3. *Irrigation effects.* Irrigation in this experiment had little effect on the development of tiprot (Table 4). By the end of the shelf-period spears from the fern irrigation treatment had slightly less tiprot than the unirrigated treatment, and some minor interactions were detected between the factors being tested. The magnitude of these effects was small compared to the difference between the two cultivars in the experiment, with Jersey Giant having much less tiprot than UC157 in the early stage of the shelf-period. This difference had disappeared at the 5-day assessment.

The greatest effect observed in this experiment was that of harvest date. Spears from all treatments harvested in early October developed much lower levels of tiprot than those harvested a fortnight later, and by mid-November every spear developed tiprot during the 4 weeks cold storage period.

4. *Physiological factors in tiprot.*

a. *Protein content.* Spear tips from the 'good' plants with low susceptibility to tiprot had lower protein content at harvest than spears from 'medium' and 'inferior' plants (Fig 3). This difference continued through the protein accumulation and early protein loss phases but distinctions between the three groups was lost at 72 h after harvest. There is no obvious explanation for a relationship between protein content and tiprot. The higher protein content of the more susceptible plants could contain a more accessible pool of protein for catabolism, or it could be merely the corollary of lower pools of other constituents (e.g. soluble carbohydrates).

b. *Soluble carbohydrates.* Spear tips of 'inferior' plants had much lower soluble carbohydrates at harvest than the other plants, and levels remained lower throughout the 72 h postharvest period (Fig 4). A lower pool of soluble carbohydrate could well be a critical element in the metabolism of spears cut off from their assimilate supply. It could result in an earlier shift to use of protein as a metabolic substrate and consequent ammonia accumulation.

c. *Ammonia.* Ammonia levels were slightly higher in the spear tips of 'inferior' plants at harvest than in the other plants and remained higher throughout the postharvest period (Fig 5). At 72 h ammonia in tips from 'inferior' plants had almost trebled and the spread between the three groups had increased markedly. These data encourage the conclusion that use of protein as a metabolic substrate leads to the accumulation of toxic levels of ammonia in the tissue. In some way the 'inferior' plants are predisposed to this metabolic course, possibly through their lower reserves of soluble carbohydrate at harvest.

Conclusions

1. Predisposition to tiprot is probably related to the genotype of the plant. Selection for this characteristic may provide a useful method for reducing tiprot susceptibility.

2. Crop management may influence tiprot susceptibility but effects are likely to be minor.

3. Tiprot occurrence varies dramatically during the season with early season spears being much less susceptible than late season spears.

4. Spear tips from 'inferior' plants were higher in protein and ammonia and lower in soluble carbohydrate than spear tips from 'good' plants. It is probable that spears need high levels of soluble carbohydrates at harvest to delay the switch into protein breakdown that generates ammonia accumulation. Ammonia could be the toxic factor causing the tissue breakdown known as tiprot.

References

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Table 1. Tip rot development (%) in spears of 41 cultivars after 4 weeks storage at 0°C, assessed during a shelf-period at 20°C.

Cultivar	Days after storage		
	0	3	5
P66	29	48	74
32x22-8	29	39	73
Tainan No.3	31	48	56
Junon	34	53	71
Huchels Leistunsualese	36	47	58
277Cx22-8	38	42	65
UC72	41	67	94
Minerve	43	59	67
C1	43	58	91
56x22-8	43	64	83
Viking 2K	46	62	80
Lucullus	48	56	67
Desto	49	64	69
Limbras 18	49	58	76
227Ex22-8	51	58	79
Steline	52	70	91
NUS54	54	60	68
Diane	54	61	70
T6	54	63	89
UC157	55	64	85
27x22-8	57	63	97
S138	58	70	75
Limbras 26	59	61	74

Cultivar	Days after storage		
	0	3	5
UC 147	59	81	92
Early of Argentieul	61	72	84
UC 800	61	70	78
Viking	63	66	85
Switzinger Meistershlusse	64	72	85
Mira	65	69	87
WSU 1	66	75	86
UC 157(F2)	68	72	83
Tainan No.1	71	74	85
Limbras 10	71	85	92
Tainan No.2	72	85	92
Limbras 22	72	81	86
California 500	72	73	82
Larac	76	78	85
Aneto	77	82	95
T1	79	87	100
Cito	84	86	94
Bruneto	93	94	100
Significance	**	**	**

Significance level of mean deviance ratio:**<0.01

Table 2. Tiprot development (%) in spears of 11 cultivars after 4 weeks storage at 0°C, assessed during a shelf-period at 20°C.

Cultivar	Days after Storage		
	0	3	5
Lucullus 310	51	68	87
Jersey Giant	55	82	94
Lucullus 234	61	83	92
Gynlim	66	81	90
UC157	68	73	85
Del MOnte 361	69	73	89
Tainan No.1	72	80	91
Larac	76	85	92
Largo 17-3	81	87	95
Franklim	83	94	93
Cito	86	98	98
Significance	**	**	*

Significance level of mean deviance ratio: *<0.05; **<0.01.

Table 3. Tiprot development (%) in spears harvested on 5 occasions during 1990, averaged over 41 cultivars. Tiprot was assessed during a shelf period at 20°C after 4 weeks storage at 0°C.

		Days after Storage		
		0	**3**	**5**
Harvest	2 Oct	22	27	64
	17 Oct	42	58	85
	31 Oct	83	93	97
	14 Nov	86	93	97
	28 Nov	84	94	97

The effect of harvest was statistically significant at <0.001 probability using analysis of deviance.

Table 4. Tiprot development (%) in asparagus spears harvested from an irrigation trial at Massey and stored at 0°C for 4 weeks followed by a period at 20°C.

		Days after storage		
		0	**3**	**5**
Cultivar	UC157	73	77	84
	Jersey Giant	45	63	82
	Significance	**	**	NS
Fern Irrigation	Yes	58	67	80
	No	62	73	85
	Significance	NS	NS	*
Spear Irrigation	Yes	62	71	83
	No	57	70	84
	Significance	NS	NS	NS
Harvest	2 Oct	8	23	44
	17 Oct	62	72	93
	31 Oct	79	94	100
	14 Nov	100	100	100
	Significance	**	**	**
Cultivar x Fern Irrig.		NS	NS	NS
Cultivar x Spear Irrig.		NS	NS	*
Fern Irrig. x Spear Irrig.		*	NS	NS

Significance refers to the probability level of the mean deviance ratio occurring by chance: ** represents <0.01; * represents 0.01-0.05; and NS represents non-significance or >0.05.

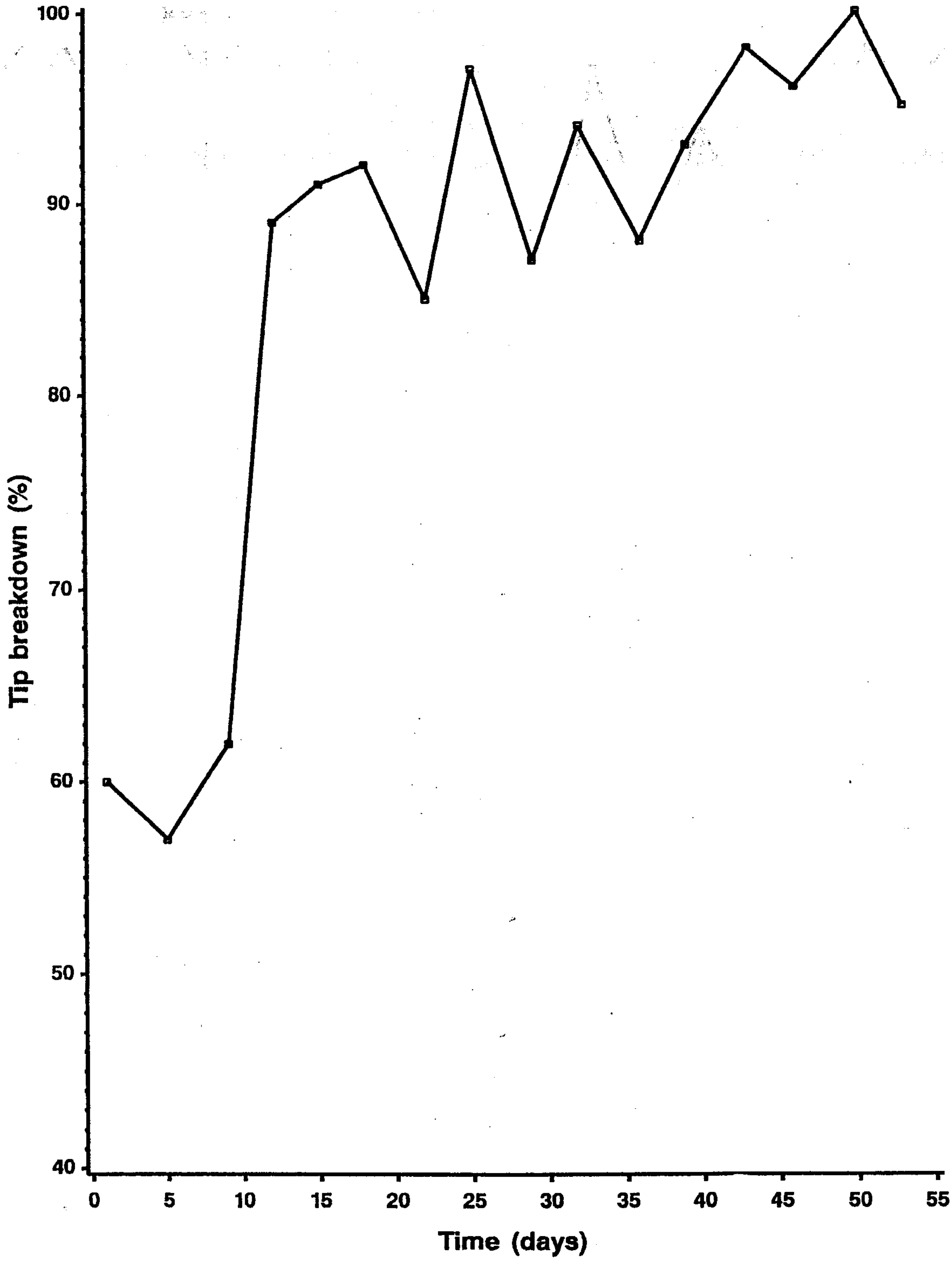

Fig 1: Development of tiprot during the season in spears averaged over 400 Mary Washington plants in 1988. Initial harvest was 17 October (Day 0), and percentage of spears with tiprot was assessed after 4 weeks storage at 0°C followed by 5 days at 20°C.

Fig 2: Development of tiprot over three seasons in spears from 'good', 'medium' and 'inferior' plants. Each group comprised 11 plants selected on the basis of 1988 data, and tiprot was assessed after 4 weeks storage at 0°C followed by 5 days at 20°C.

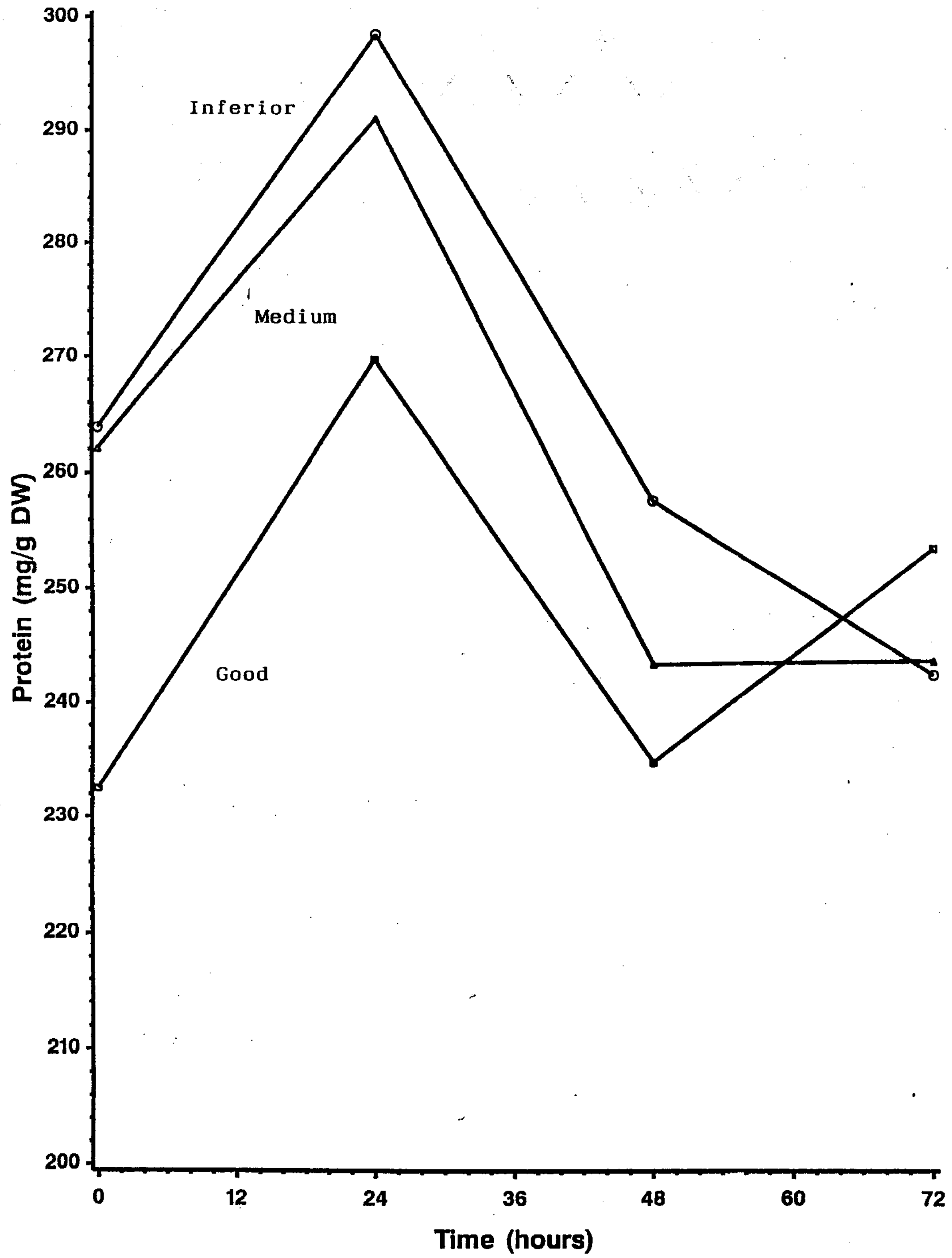

Fig 3: Protein content of spear tips from plants grouped according to their susceptibility to tiprot, harvested in 1990. Spears were held at 20°C for 72 h after harvest.

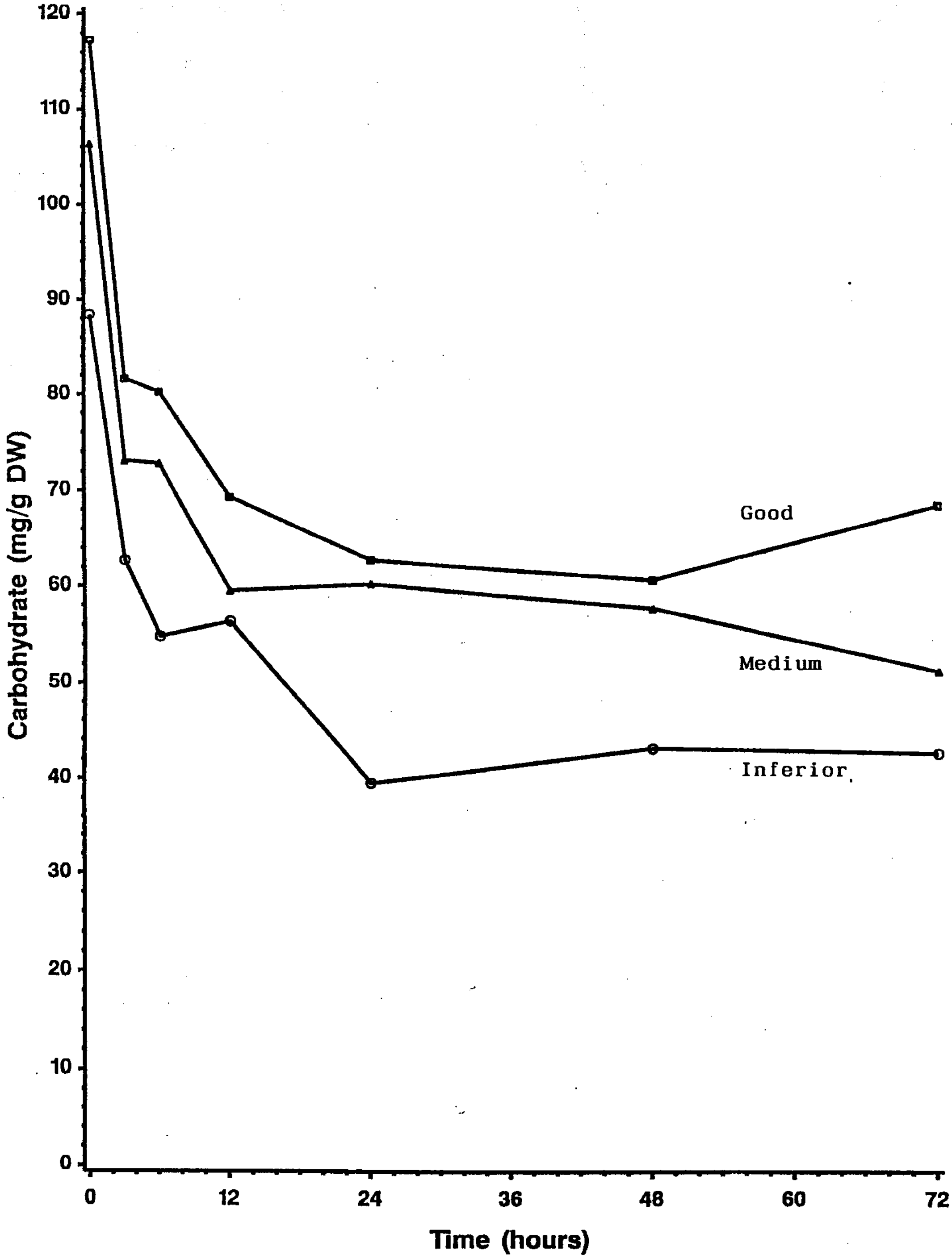

Fig 4: Soluble carbohydrate content of spear tips from plants grouped according to their susceptibility to tiprot, harvested in 1990. Spears were held at 20°C for 72 h after harvest.

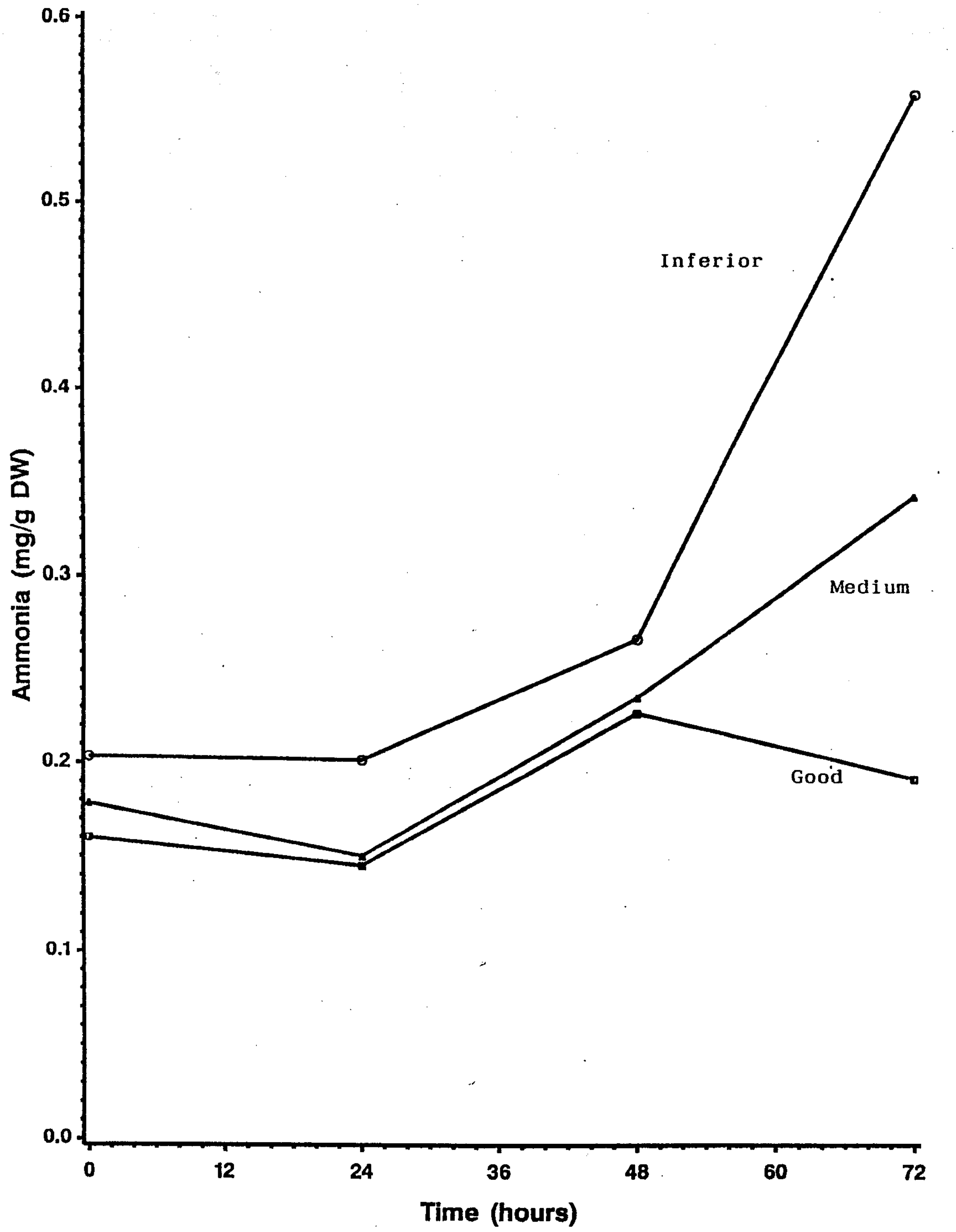

Fig 5: Ammonia content of spear tips from plants grouped according to their susceptibility to tiprot, harvested in 1990. Spears were held at 20°C for 72 h after harvest.