FOREST & FARM PLANTATION MANAGEMENT COOPERATIVE

THE EFFECTS OF A WAIRARAPA SHELTERBELT ON AGRICULTURAL PARAMETERS

M.F. Hawke, A.G. Gillingham & D. Bell

Report No. 47 May 1998

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EXECUTIVE SUMMARY

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Shelterbelts are a common feature on New Zealand farms, but their presence is more noticeable on the plains and exposed pastoral situations. Historically they have produced poor quality timber, but the main purpose of shelterbelts is to provide shelter for animals and crops. In the Wairarapa, shelterbelt plantings have been designed to enhance the landscape, ameliorate the effect of strong winds and soil erosion, provide shelter and produce good quality timber.

This three year study measured the effects of a designed shelterbelt on pasture growth and soil related aspects at distances adjacent to both aspects. The results indicated that the shelterbelt modified the pasture production profile in the sheltered zone, but statistically there were no shelter effects on total pasture production. There were reductions in pasture production close to the shelterbelt and increases beyond the root and shading zone. However, any real differences beyond the root zone were masked by the natural variability of the pasture and the degree of fertility transfer that occurred.

CONTENTS

1.0 INTRODUCTION

The role of shelterbelts on farms are multifold, but generally aim to provide protection and reduce wind speed. Benefits may include erosion control, animal welfare, crop protection, aesthetic appearance and cash returns.

The Wairarapa district represents a climatic zone where strong NW winds dry out the soil during summer months and where cold southerly winds in winter are prevalent. The Wellington Regional Council have planted several shelterbelts in the district surrounding Masterton, to help reduce the effects of strong winds but also to grow a supply of well managed timber.

The study was undertaken to measure the effects of a designed shelter belt on pasture growth and soil related aspects under a typical pastoral farming regime.
This was to be achieved by measuring the productivity of pasture on aspects predominantly sheltered from, or exposed to, the prevailing northwesterly wind. In Wairarapa this is seen as a limiting factor to agricultural productivity.

The principal effects of a shelter plantation relating to pasture production are two-fold:

1. Physical effects of the trees on the soil from competition for nutrients and moisture, shade, litterfall and rain interception.
2. Sheltering effects resulting from reduced wind speed. These include direct and complex interactions on plant growth associated with soil moisture and stomatal function (through evaporation and plant transpiration), or the reduction in physical damage (desiccation). Stock-related interactions occur from behaviour changes associated with shade and temperature improvements. These lead to effects on pasture from trampling and nutrient deposition.

With co-operation between Wellington Regional Council and AgResearch , several agricultural production parameters were measured over a three year period from 1993-1996.

1.1 Shelterbelt Details and Trial Description

A two row shelterbelt of *Pinus radiata* (4 year aged cuttings) and *Leyland cypress*(Leighton Green) was planted in a northeast - southwest orientation in 1985 on a property adjoining Wiltons Road, 3 km south of Masterton (Appendix 1). This shelterbelt is considered to be well designed and managed. The property is flat, summer dry with shallow stony soils (Tauherenikau stony silt loam soil type). The soil has a wind erosion rating of 'severe'. Wind profile data from East Taratahi (NIWA Station D15064),2 km east of the shelterbelt over the 3 year measurement period confirms that the strongest winds occur from the NW and W sectors (Moore, *pers. comm..*). The district has an average annual rainfall of 950 - 1020 mm, predominantly falling in the winter and spring.

Forest Research have permanent sample plots (PSPs) in the shelterbelt and have measured the optical porosity value at 20.25% (% air space) at tree age 11 (Horvath, *pers comm*). The mean tree height in years 1993, 94 and 95 was 10.5, 12.4 and 12.8 m respectively.

In this study, the 200m zone on the SE aspect was 16.8 tree heights from the shelterbelt. According to published literature (Sturrock, 1972) this distance represents 80-90% of free unobstructed wind (ie. unsheltered zone). By contrast, the 120m zone on the NW aspect was 10.1 tree heights from the belt. On the windward aspect, this distance represents an unsheltered zone (Caborn , 1965). However, a further shelterbelt situated 220m west of the trial belt may have affected this zone. It is therefore not possible to compare the results from the NW and SE aspects on this trial.

1.2 Measurement Details

Three years of pasture production measurements were made using a small plot modified rate of growth (ROG) technique at a range of distances adjacent to both aspects of the shelterbelt (1993-1996). Pasture samples were oven dried and dry matter/ ha calculated.

Pasture herbage species analysis by dissection was measured in December, 1993, March 1995 and 1996 and the % species composition calculated on a dry weight basis.

Soil nutrient status was measured in December, 1994 from a bulk sample at each measurement distance by AgResearch Quick Test analysis.

Herbage was analysed in December 1993 and 1994 for Nitrogen, Phosphate and Potash contents.

Soil moisture status was calculated on a % dry weight basis in February and December, 1994.

A glasshouse/ nursery study was completed in 1993/ 1994 on soil collected in August 1993 from a range of distances on the leeward (SE) aspect only of the shelterbelt, placed in plots and sown with ryegrass. Pasture production was measured during the growing season and soil nutrient status analysed at the commencement of the trial.

The data was analysed using Flexi 2.4a (Bayesian smoothing programme) and the fitting of a spline with an asymptote feature.

2.0 RESULTS

2.1 Pasture Production

Results from each of the three years indicated a similar pattern (Table 1) ie., a depression in pasture growth adjacent to the trees at the 5m distance. At a 95% confidence interval, the total of the three years production data indicated a gradual increase in dry matter from 5 - 80 m distance on the SE. aspect (Appendix A, Figure 1), then a small decline with increased distance. This effect was not apparent on the NW. aspect although production at the 5m distance was lower than at all other sites (Appendix A, Figure 2).

Table 1: Total Annual Pasture Yields (kg DM/ha)

Year	1993/94	1994/95	1995/96	Average - all years
Distance (m)				
Aspect - SE				
5	9107	10418	6280	8602
10	10768	12434	10593	11265
20	11481	13463	11921	12288
40	12658	15708	11971	13446
80	14606	15710	12152	14156
120	11552	17341	11746	13546
160	9994	15964	11499	12486
200	11422	15556	10559	12402
Aspect - NW				
5	7721	10214	6253	8063
10	12244	13387	11273	12301
20	11687	14001	11222	12303
40	10147	12765	10380	11097
80	11802	15498	10324	12541
120	13051	15558	10084	12898

Seasonal production trends were similar on the SE. aspect, with a benefit to shelter between the 40 - 120 m zone and then a subsequent decline up to the 200m distance. On the NW. aspect, seasonal trends were also similar to the pattern of annual production (Table 2).

Table 2: Average Seasonal Dry Matter Production (kg DM/ha).

Distance (m)	Spring (7)*	Summer (5)*	Autumn (4)*
Aspect - SE			
5	4437	1999	2166
10	5466	3116	2683
20	6015	3167	3106
40	6739	3270	3436
80	7417	3242	3497
120	6363	3226	3958
160	6359	2992	3136
200	6417	2915	3181
Aspect - NW			
5	4729	1421	1912
10	6585	3084	2633
20	6626	2760	2917
40	5326	3001	2771
80	6173	3202	3166
120	6489	3283	3126

*( ) = number of cuts

Where the total "sheltered" areas were compared on a seasonal and annual basis with the ' open pasture' zone, there were no significant yield differences (Table 3) on either a seasonal or annual yield basis.

Table 3: Effects of Shelter on Seasonal and Annual Pasture Dry Matter Production (kg DM/ ha).

	NW. Aspect		**Approx standard error**	**SE. Aspect**		**Approx standard error**
	Open Pasture+	**Sheltered ***		**Open Pasture#**	**Sheltered***	
Spring 1993/94	5895	6073	1037	6104	6025	850
Summer "	3029	2983	576	2770	2645	813
Autumn "	2548	2538	416	2862	2343	561
TOTAL	11633	11862	693	11998	11018	1750
Spring 1994/95	8684	8206	493	7426	7138	940
Summer "	3516	3820	318	4448	3739	298
Autumn "	3746	3454	297	3306	3144	267
TOTAL	15994	15520	954	15398	14017	1282
Spring 1995/96	5074	5163	423	4898	4563	455
Summer "	2292	2280	170	2431	2413	279
Autumn "	3520	3090	411	3140	3118	496
TOTAL	11093	11374	823	10184	10100	1073

+ NW. Open Pasture is 120m from shelterbelt.

* NW. & SE. sheltered is the composite area of 5-80 & 5-160m respectively for the two aspects.

\# SE. Open Pasture is 200m from shelterbelt.

2.2 Pasture Composition

There was no effect of shelter on the grass component in any year or on either aspect. The clover percentage increased from the 5m to the 10m distance in each of the three years on the SE aspect. On the NW aspect, clover percentage increased at the autumn dissections but declined from the 5-10m distance in the summer analysis (Table 4). At the 95% confidence interval, there was minimal effect of shelter on pasture composition.

Table 4: Herbage Dissection (% contribution)

Distance (m)	December 1993			March 1995			March 1996		
Aspect-SE	Grass	Clover	Weeds	Grass	Clover	Weeds	Grass	Clover	Weeds
5	88	10	2	79	17	4	81	19	0
10	72	23	5	58	35	7	67	31	2
20	58	32	10	63	33	4	68	23	9
40	81	12	7	66	25	9	90	8	2
80	58	39	3	62	36	2	70	30	0
120	91	9	0	73	27	0	79	20	1
160	75	25	0	69	29	2	78	15	8
200	67	33	0	65	30	5	73	25	2
Aspect-NW	Grass	Clover	Weeds	Grass	Clover	Weeds	Grass	Clover	Weeds
5	61	36	3	87	1	12	71	9	20
10	79	19	2	62	29	9	76	22	2
20	72	20	8	82	15	3	77	23	0
40	60	24	16	67	23	10	88	7	5
80	92	8	0	57	25	18	78	17	5
120	67	24	9	75	20	5	68	28	4

2.3 Soil Nutrient Status

Soil K levels tended to be higher and soil pH lower, close to the shelter and at the 200m distance, but magnesium, phosphate and sulphur levels were similar across all distances (Table 5). Soil P was highest at the furthest distance from shelter on both aspects but whether this is a real effect is not clear from this single sampling (Appendix A, Figures 3 & 4).

Table 5: Soil Nutrient Levels (December, 1994)

Distance(m)	Soil Quick Test Units					
Aspect-SE	pH	Ca	K	P	Mg	S
5	5.2	9	14	12	21	6
10	5.8	13	4	11	23	4
20	5.8	12	4	8	22	3
40	5.7	13	7	11	22	6
80	5.7	11	6	13	19	4
120	5.7	9	4	12	15	3
160	5.6	8	6	11	17	4
200	5.4	8	13	18	22	5
Aspect-NW						
5	5.4	6	8	10	19	4
10	5.8	11	7	9	19	9
20	5.6	10	5	9	19	5
40	5.7	10	8	11	20	4
80	5.8	11	5	10	20	5
120	5.4	7	7	18	18	6

2.4 Herbage Nutrient Status

At the 95% confidence level, pasture nitrogen content gradually decreased with increasing distance from the shelterbelt on the NW. aspect in both December, 1993 and 1994 but increased over the 5-80m on the SE. aspect in December, 1993 (Appendix A, Figures 5, 6 & 7). This trend did not occur on the SE. aspect in the December, 1994 sampling.

Other results were quite variable and there was no trend related to aspect or distance from the shelter (Table 6). Levels were adequate for pasture growth.

Table 6: Herbage Nutrient Content (%)

Aspect	Distance (m)	Nitrogen	Phosphorus	Potash
December 1993				
SE.	5	2.38	0.35	2.24
	10	2.76	0.35	1.80
	20	2.70	0.35	2.19
	40	3.04	0.30	2.39
	80	3.12	0.39	3.48
	120	3.21	0.39	2.37
	160	3.17	0.34	2.07
	200	3.02	0.34	2.97
NW.	5	3.23	0.28	2.77
	10	3.28	0.29	2.62
	20	2.70	0.39	2.22
	40	2.48	0.31	2.49
	80	2.52	0.36	2.80
	120	2.42	0.32	2.29
December 1994				
SE.	5	3.87	0.26	2.92
	10	2.99	0.29	1.84
	20	2.59	0.27	2.15
	40	3.22	0.30	2.58
	80	3.39	0.34	2.14
	120	3.51	0.28	2.31
	160	3.06	0.30	2.49
	200	2.71	0.26	2.87
NW.	5	3.13	0.28	2.40
	10	3.25	0.34	1.75
	20	2.73	0.32	2.18
	40	2.74	0.31	2.36
	80	2.67	0.30	2.34
	120	2.31	0.33	2.17

2.5 Soil Moisture

In December, 1994 there was a pattern of lower soil moisture at the 5m distance, and a general increase in distance from shelter on both aspects. In the December 1994 sampling, in dry conditions, and a soil moisture stress situation, soil moisture levels were lower on the NW than on the SE aspect (Table 7 and Appendix A, Figures 8 & 9). Although soil moisture levels were lower at the 5m distance in February, 1994 there was no general trend of increases past the 10m distance. At this time overall soil moisture levels were higher.

Table 7: Soil Moisture Status

Aspect	Distance (m)	% by weight at 4.2.94	% by weight at 12.12.94
SE.	5	20.5	14.4
	10	25.7	16.8
	20	25.1	17.4
	40	23.7	17.4
	80	24.6	21.0
	120	21.9	21.1
	160	23.0	21.0
	200	21.9	22.4
NW.	5	18.0	12.6
	10	23.3	13.3
	20	24.4	14.3
	40	23.1	14.6
	80	20.5	15.2
	120	22.0	17.8

2.6 Glasshouse/Nursery Study

This trial was conducted to indicate the influence of soil nutrient status on pasture growth pattern in the absence of any shelter effects.

Results clearly showed that higher pasture growth occurred at the 40 - 160m distance from the shelterbelt at the 95% confidence interval (Table 8 and Appendix A, Figure 10) . This was supported by similarities in the pattern of soil P and Total N status, and to a lesser extent soil K levels as indicators of soil fertility (Table 8 and Appendix A, Figures 11, 12 & 13).

Table 8: Glasshouse/Nursery Study (Pasture Production and Soil Nutrient Status).

	Pasture Production	Soil Quick Test Nutrient Status		
	Total yield - 6 cuts	Olsen P	K	TN
Distance (m)	Kg DM/ha			
5	4610	13	6	0.65
10	4275	11	4	0.61
20	4333	12	8	0.62
40	5475	17	8	0.73
80	6401	21	11	0.68
120	6203	19	15	0.81
160	5498	18	8	0.77
200	5037	16	12	0.61

3.0 DISCUSSION

The net seasonal or annual effects of shelter on pasture growth are attributable to the physical impacts of the plantation, changes to plant growth opportunities and reduced physical damage, and changes to stock behaviour leading to nutrient transfer and compaction. The contrast between hot, dry summer winds and cold wet winter storms increases the complexity of the interactions.

The overriding effect of the shelterbelt was to cause a depression in pasture growth, close to the trees but for any effects to be less well defined and consistent at greater distances. The 'open pasture' zones on both aspects may not have been completely unsheltered, suggesting that the

shelter effects may be underestimated. However the lack of a progressive trend from shelter to the most unsheltered site in any of the parameters measured suggests that any unsheltered effect was probably minimal. Seasonal differences occurred which could probably be related to climatic factors. The most obvious of these was moisture stress situations when reductions in pasture growth close to the shelterbelt were more acute.
While these results are presented on a distance from shelterbelt basis, it would be valid to proportionately weight the data for the area sheltered. The relative pasture production that is sheltered may increase but end or edge effects and land lost to grazing within the planted zone would also need to be considered.

It is apparent that the design and management of the shelterbelt created a sheltered zone from NW winds which was reflected in increased pasture production between 40 - 120 m distances on the SE aspect. The glasshouse/ nursery study showed that part of the increase in pasture yield over this distance was due to higher soil nutrient status in this zone (Hawke and Gillingham, 1995). The lower pasture yields at the 5m distance from shelter was probably due to lower soil moisture, greater tree root competition and greater soil compaction due to stock trampling at this distance.
It is possible that the difference between the two sets of soil test results was due to management differences prior to each time of sampling (ie August 1993 on the SE aspect only for the glasshouse trial, compared with December 1994 for the full trial sampling). This could have included stock grazing, sheltering and camping preferences at different times of the year, fertiliser application differences and seasonal differences in nutrient leaching.
The low level of soil moisture close to the shelterbelt is probably due to both the sheltering effect of the shelterbelt from rainfall as well as the additional utilisation of moisture by tree roots (Gillingham and Hawke, 1997).
The generally lower soil moisture levels close to the shelterbelt may largely account for the lower occurrence of white clover. White clover is relatively shallow rooting and its decline is one of the first indicators of moisture stress (Mouat, 1983).

The variability of herbage nutrient status indicates that this shelterbelt did not affect the uptake of nutrients in any differential way. There also appeared to be no relationship between pasture nitrogen content and the proportion of clover in the pasture.

Continuous microclimate measurements eg. wind run and temperature records on both aspects and at increasing distance from shelter would have provided a valuable adjunct to this study but were unable to be obtained because of serviceability and cost difficulties. It is evident however that shelterbelts such as that studied do not impose significant major effects on pasture and soil conditions which would require any modifications to routine farm management.

The shelterbelt timber yield and quality has been measured by ***Forest Research*** but is not reported in this study.

4.0 ACKNOWLEDGEMENTS

The authors wish to thank the property owners for access to the area and use of the land. Also to Wellington Regional Council for support and use of the shelterbelt. The Forest and Farm Plantation Management Cooperative provided the funding for this study.

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APPENDIX

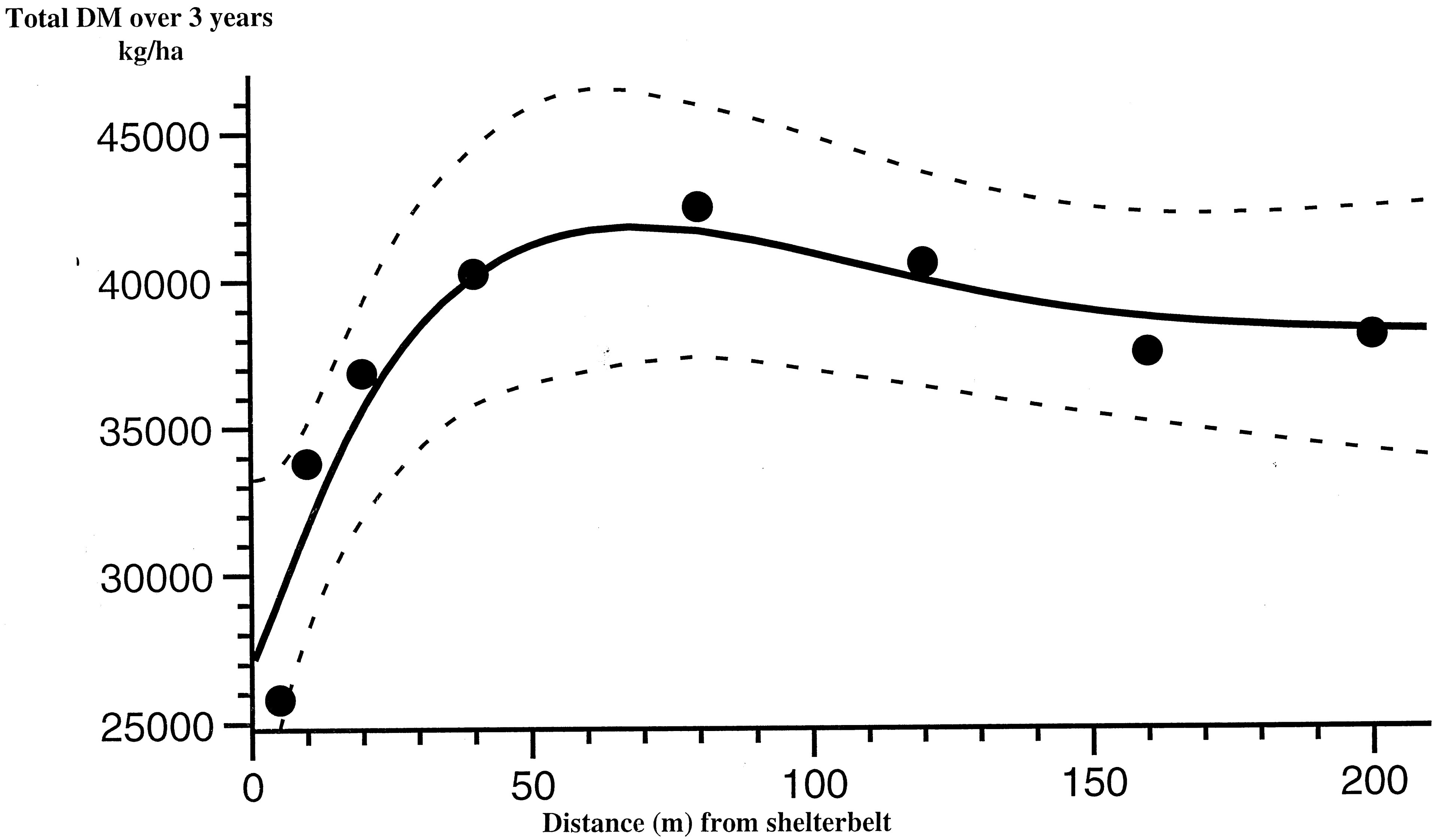


Figure 1: The effect of distance from shelterbelt on total dry matter/ha- SE aspect

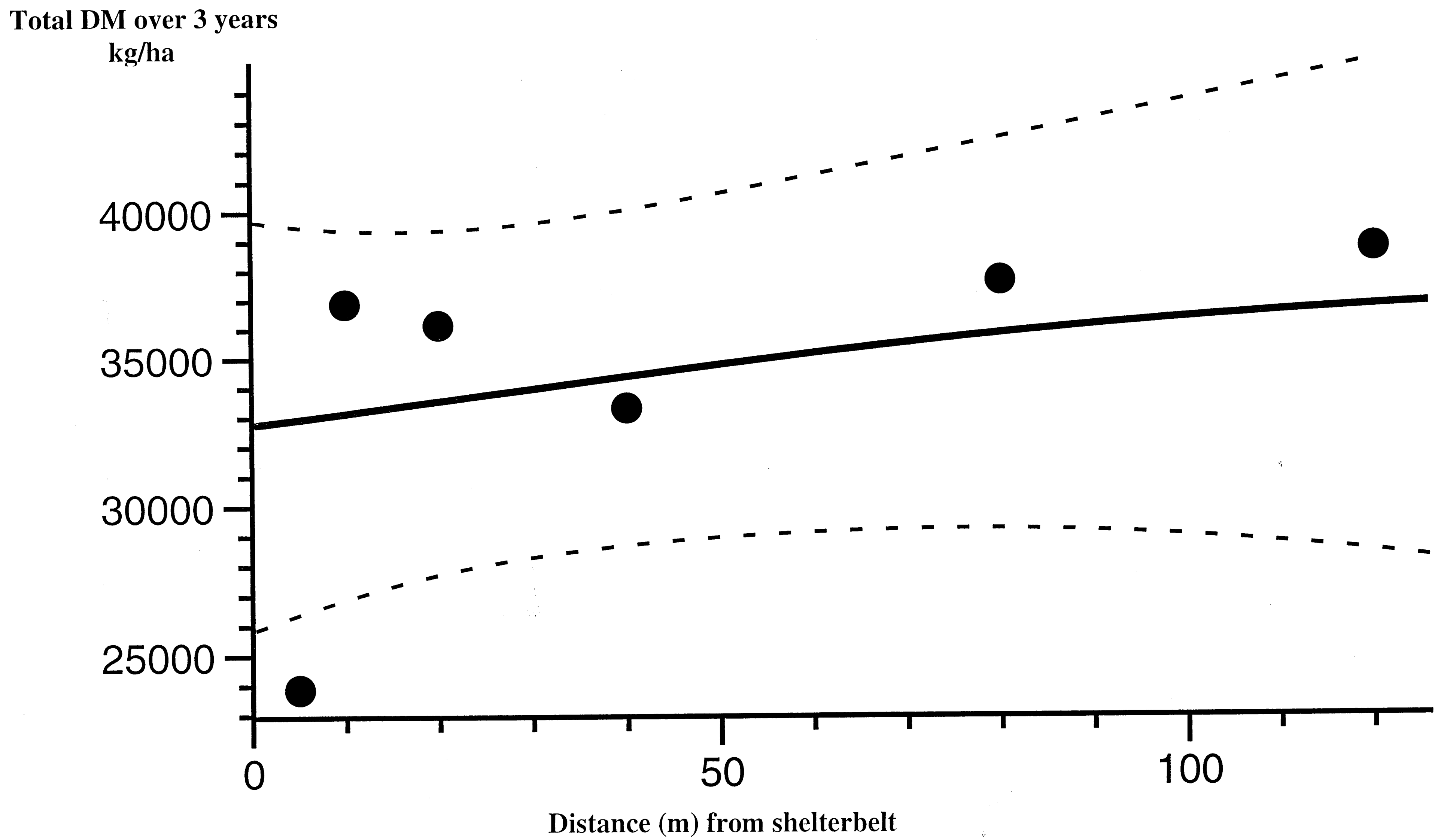


Figure 2: The effect of distance from shelterbelt on total dry matter/ha - NW aspect

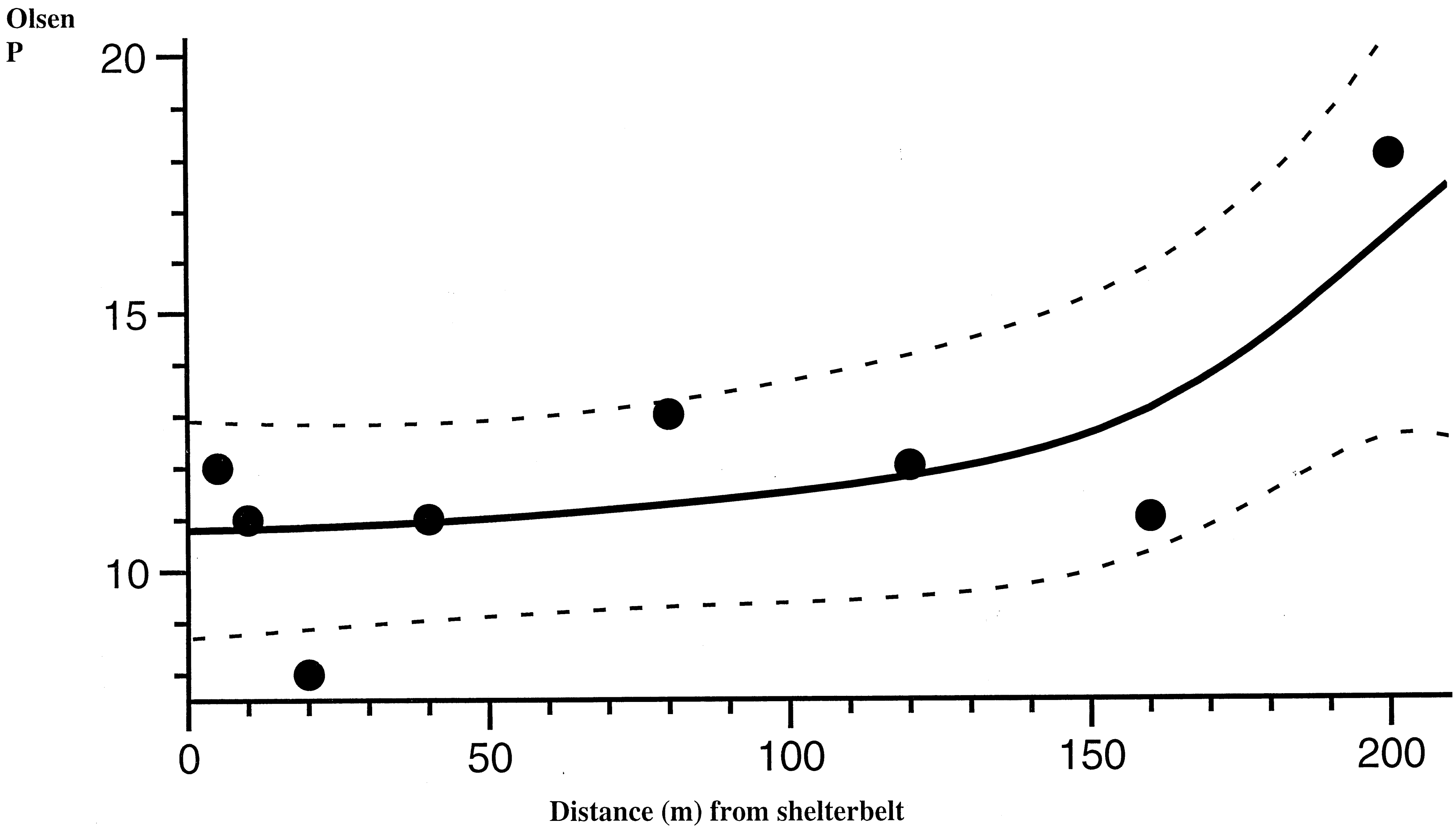


Figure 3: The effect of distance from shelterbelt on soil P status - SE aspect

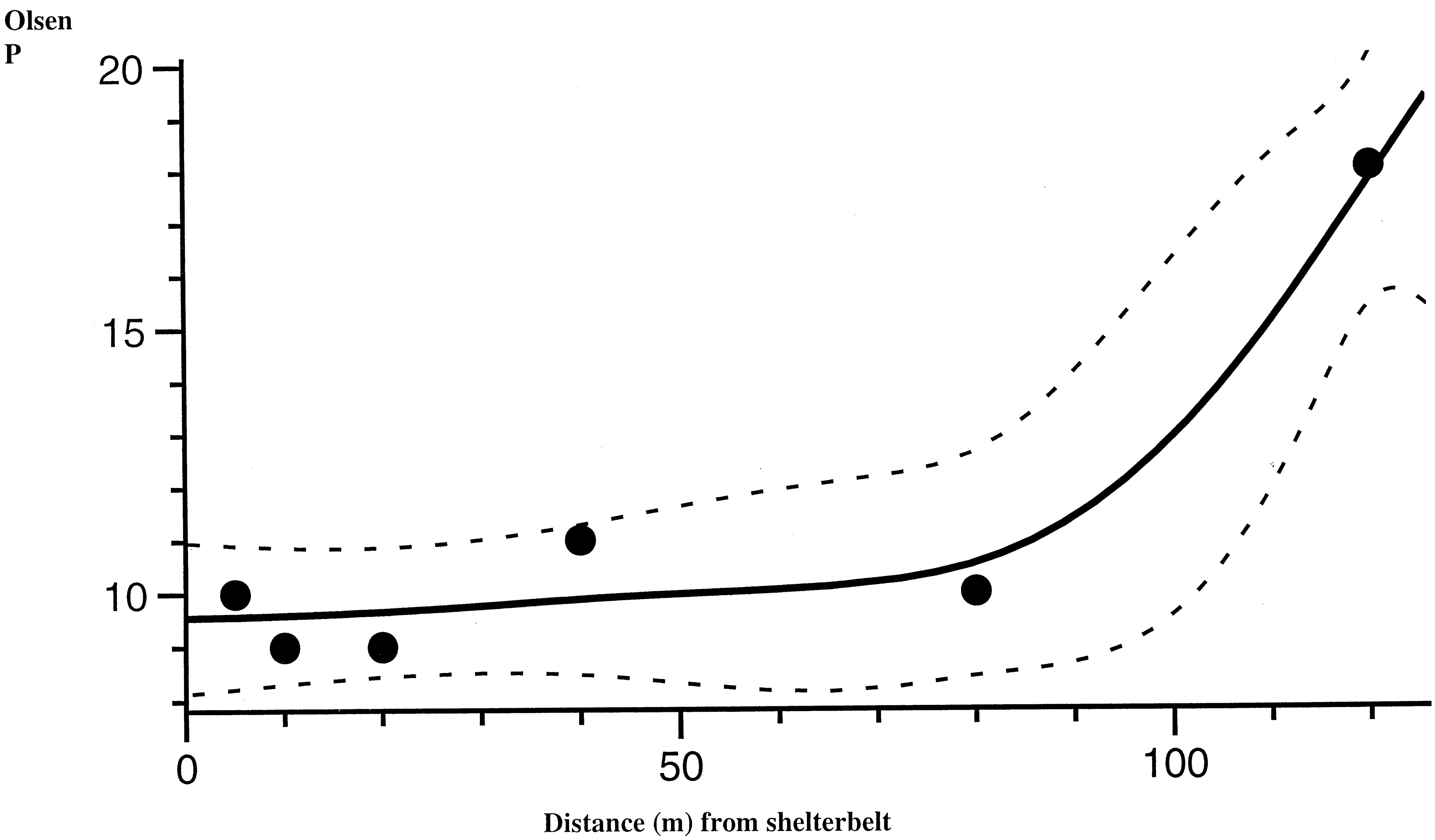


Figure 4: The effect of distance from shelterbelt on soil P status - NW aspect

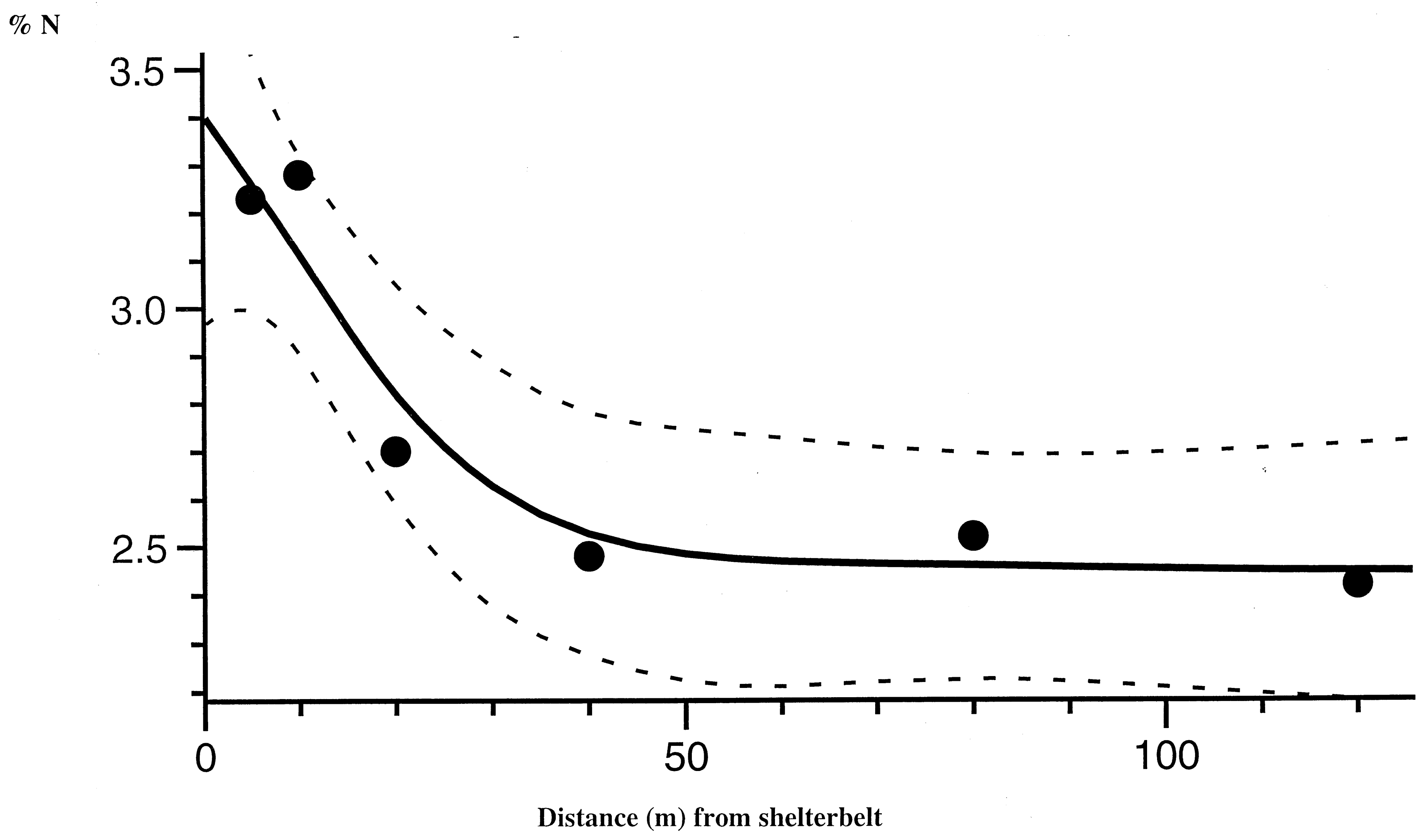


Figure 5: The effect of distance from shelterbelt on herbage N status, December 1993 - NW aspect

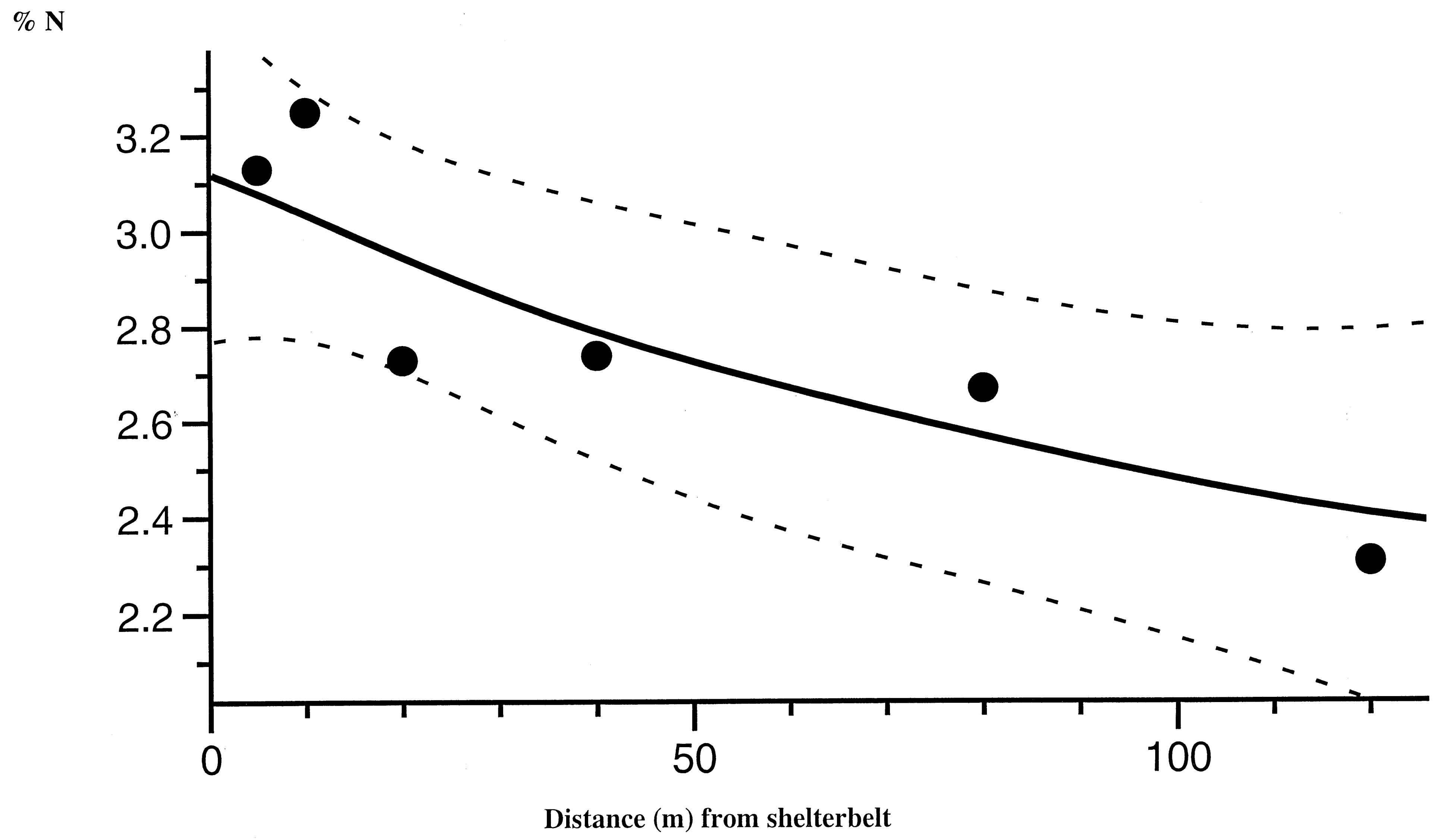


Figure 6: The effect of distance from shelterbelt on herbage N status, December 1994 - NW aspect

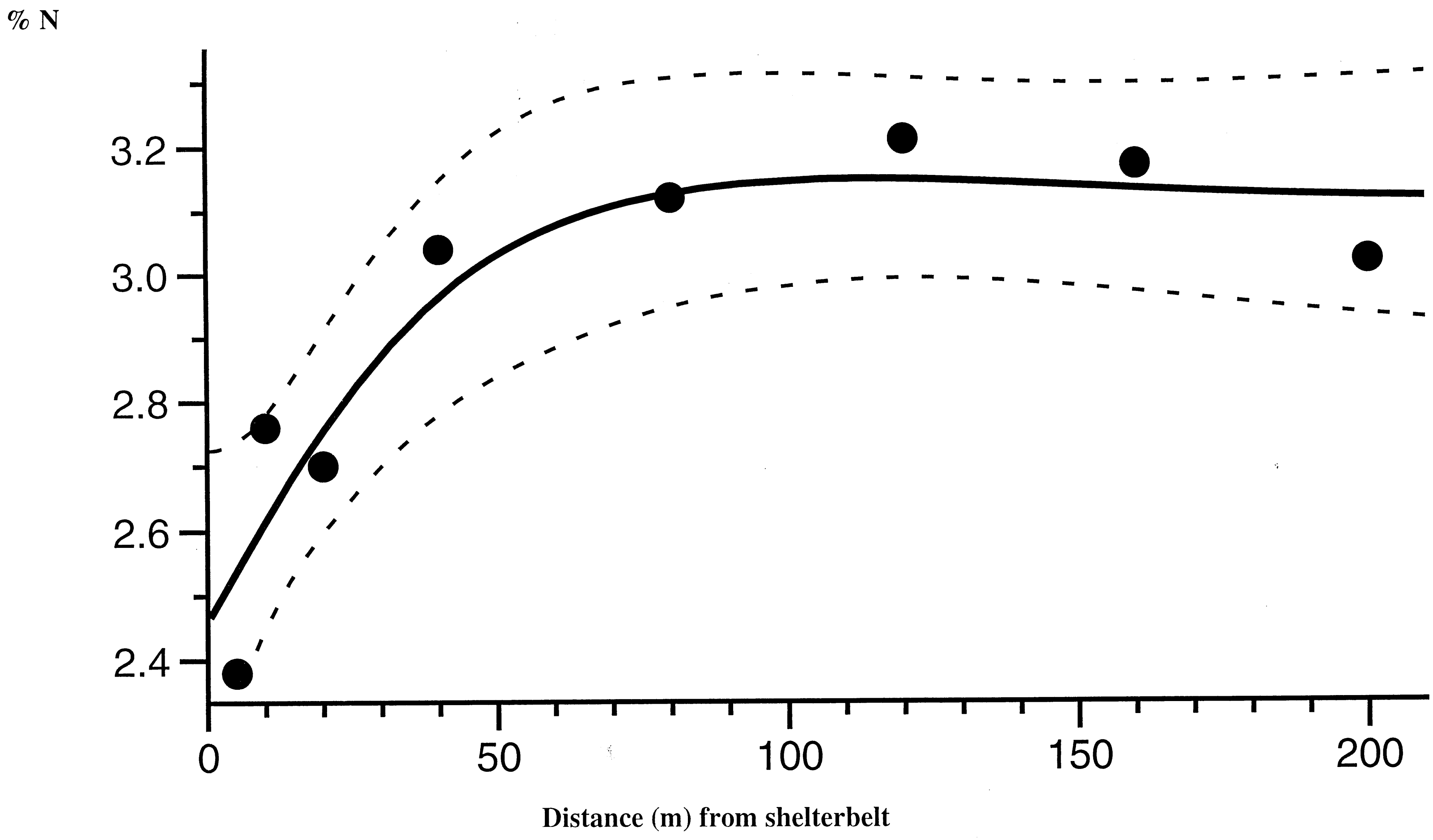


Figure 7: The effect of distance from shelterbelt on herbage N status, December 1993 - SE aspect

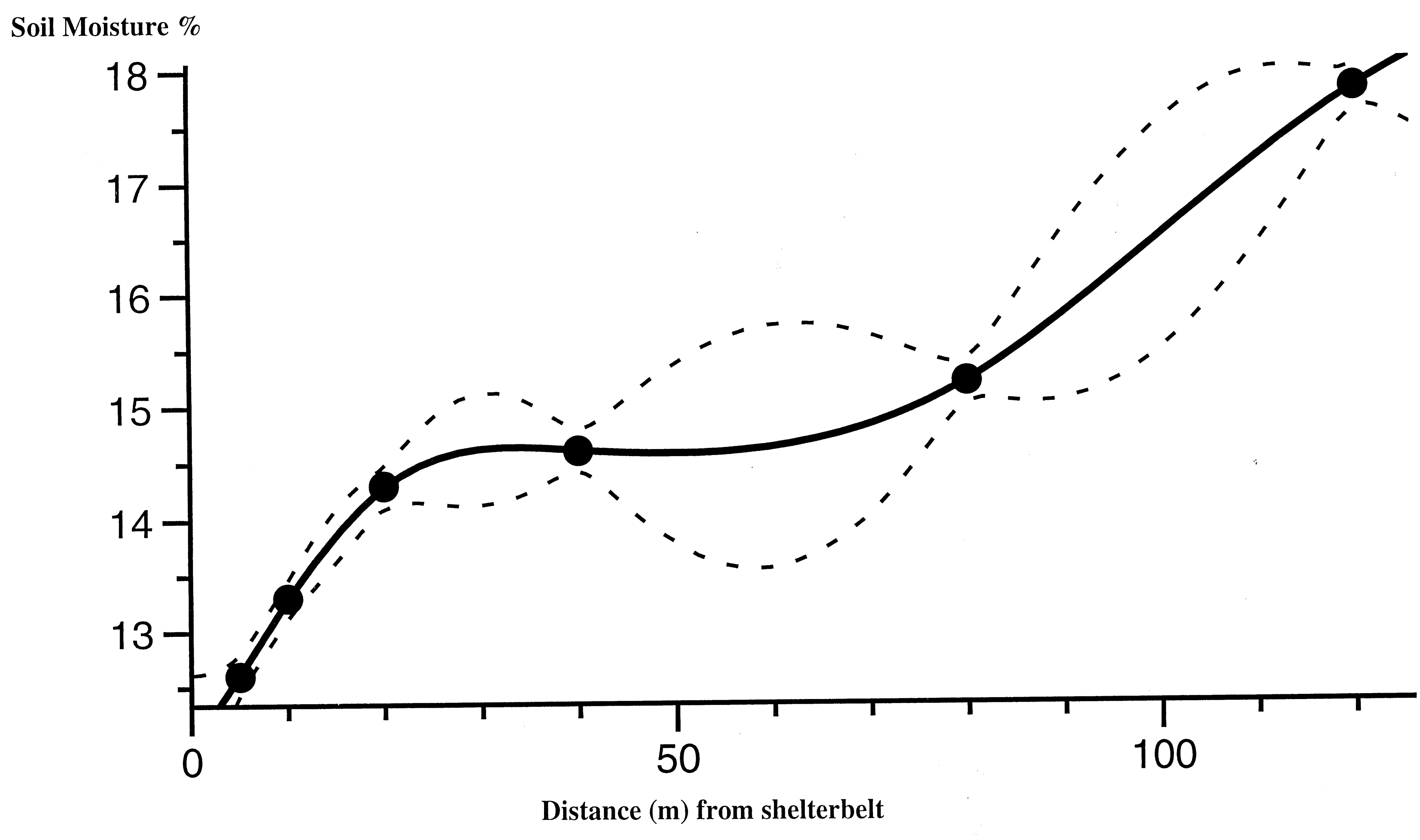


Figure 8: The effect of distance from shelterbelt on soil moisture, NW aspect

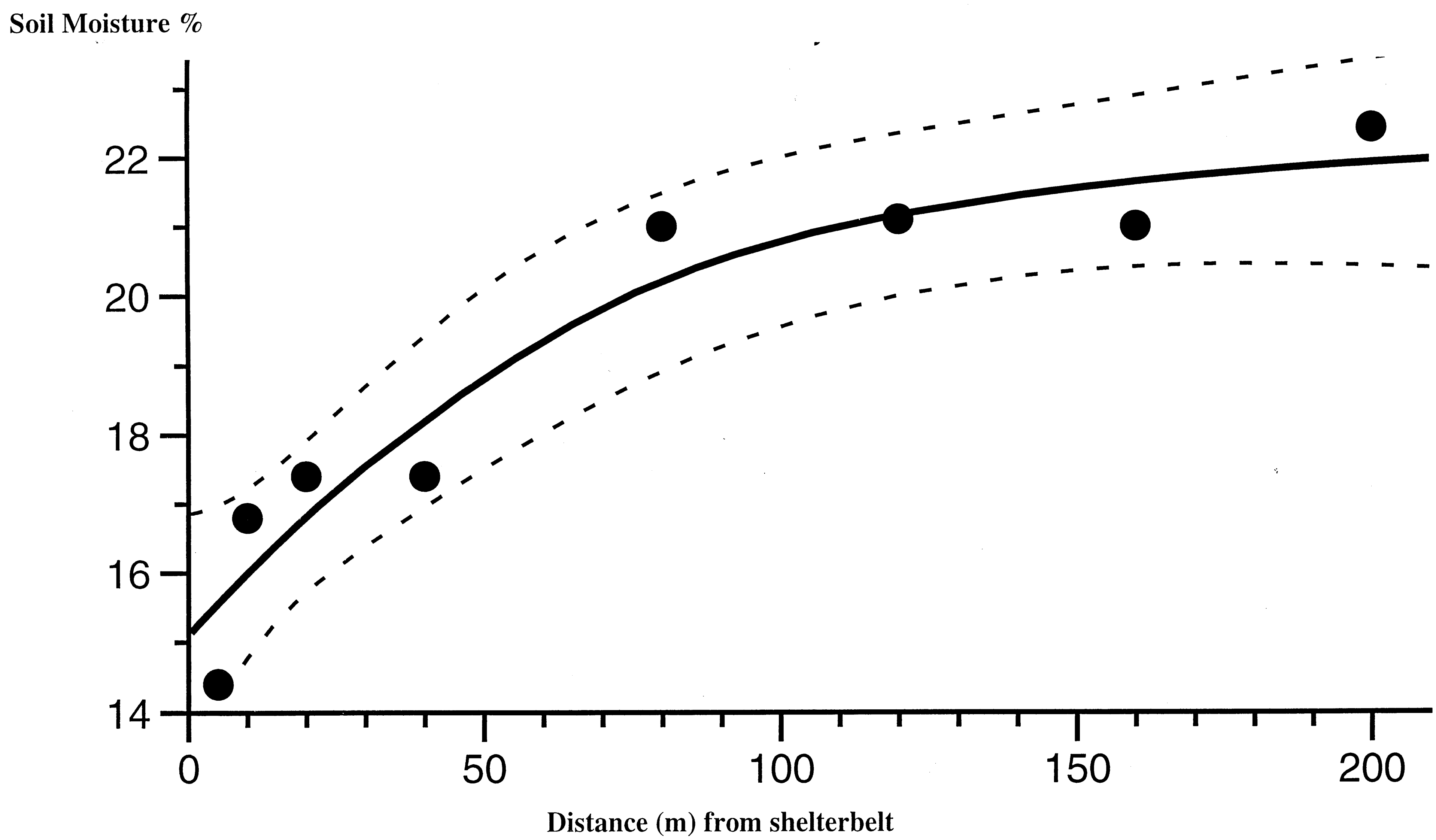


Figure 9: The effect of distance from shelterbelt on soil moisture, SE aspect

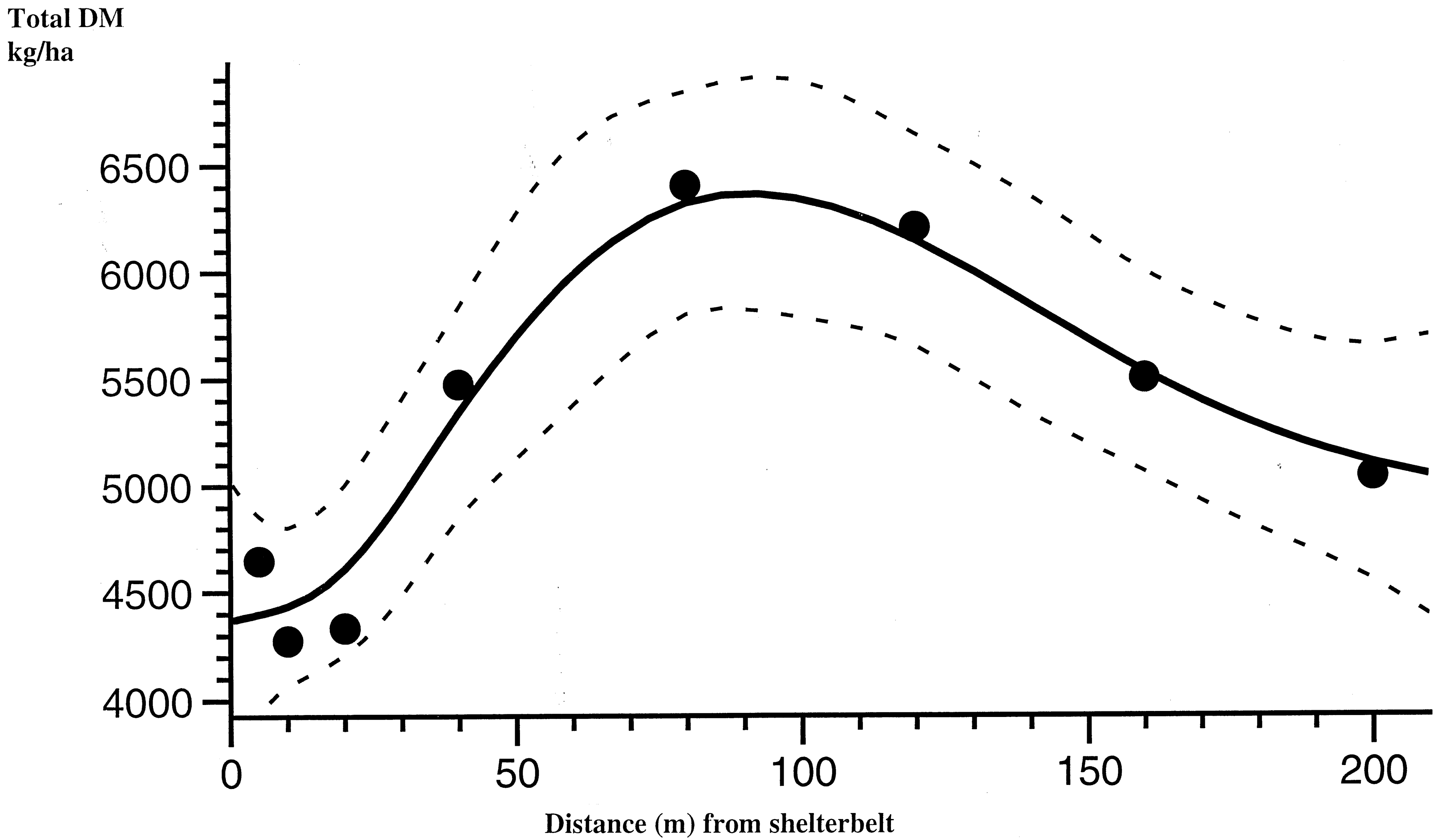


Figure 10: Glasshouse/nursery trial - the effect of distance from shelterbelt on total dry matter production.

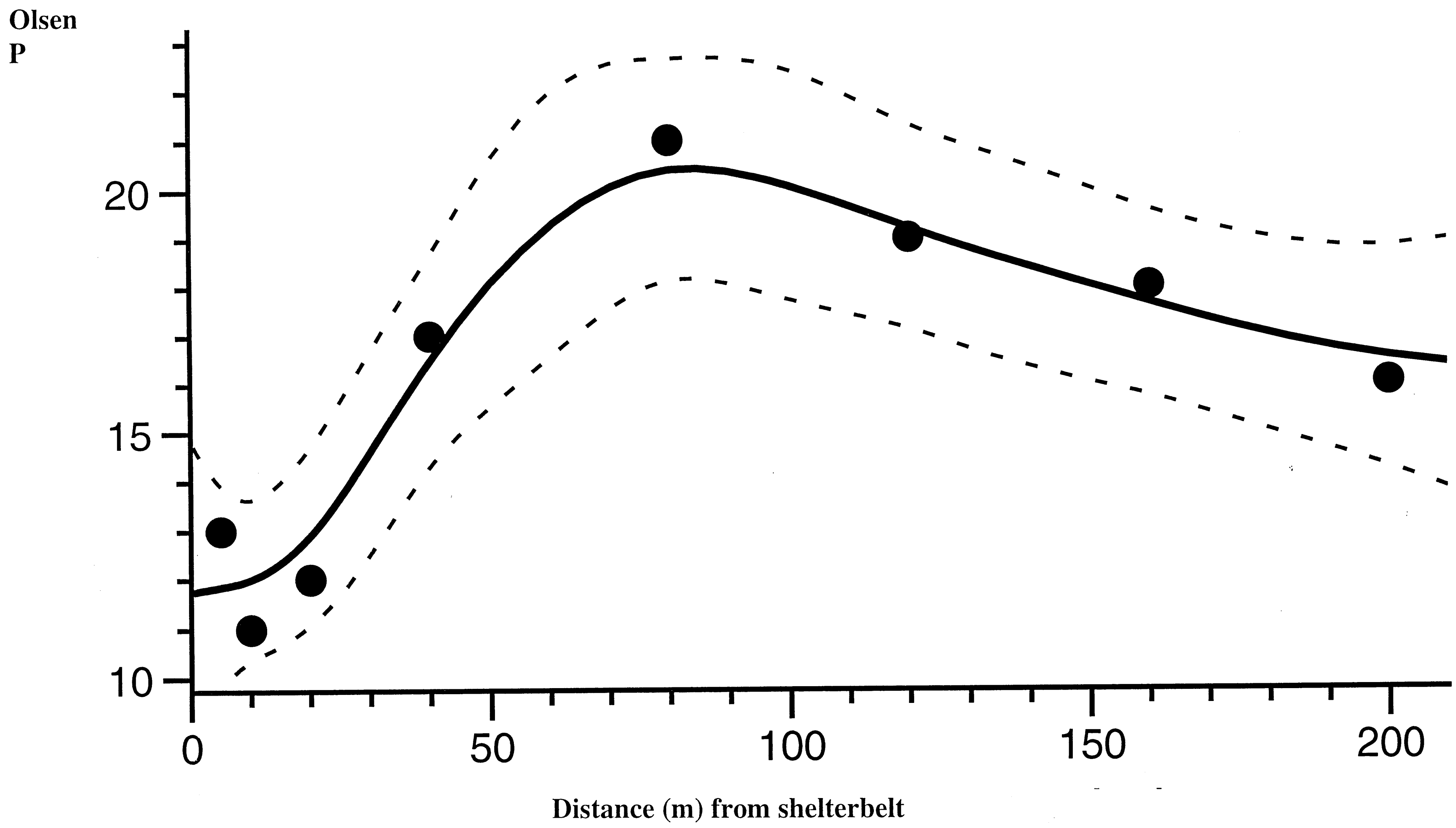


Figure 11: Glasshouse/nursery trial - the effect of distance from shelterbelt on soil P status

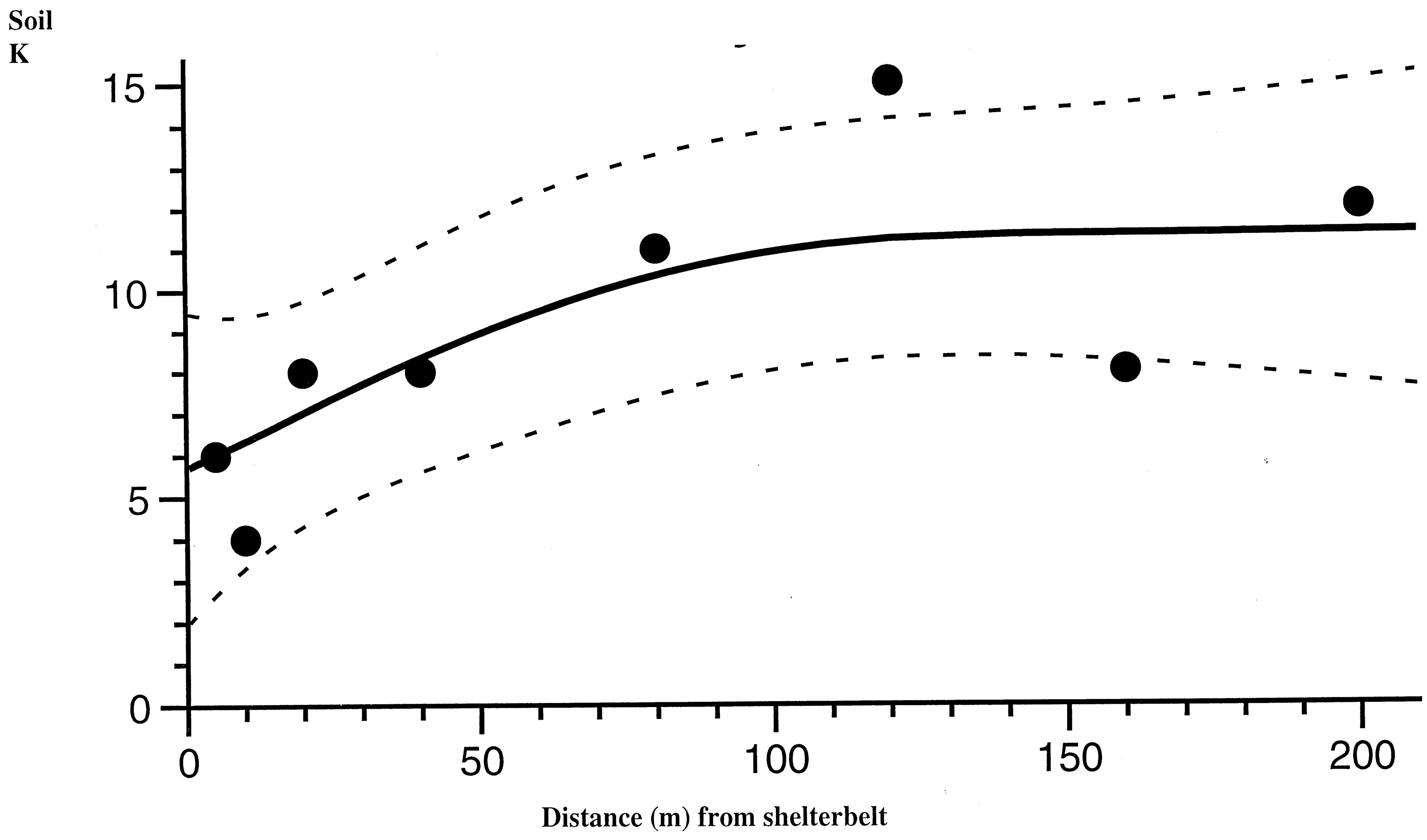


Figure 12: Glasshouse/nursery trial - the effect of distance from shelterbelt on soil K status

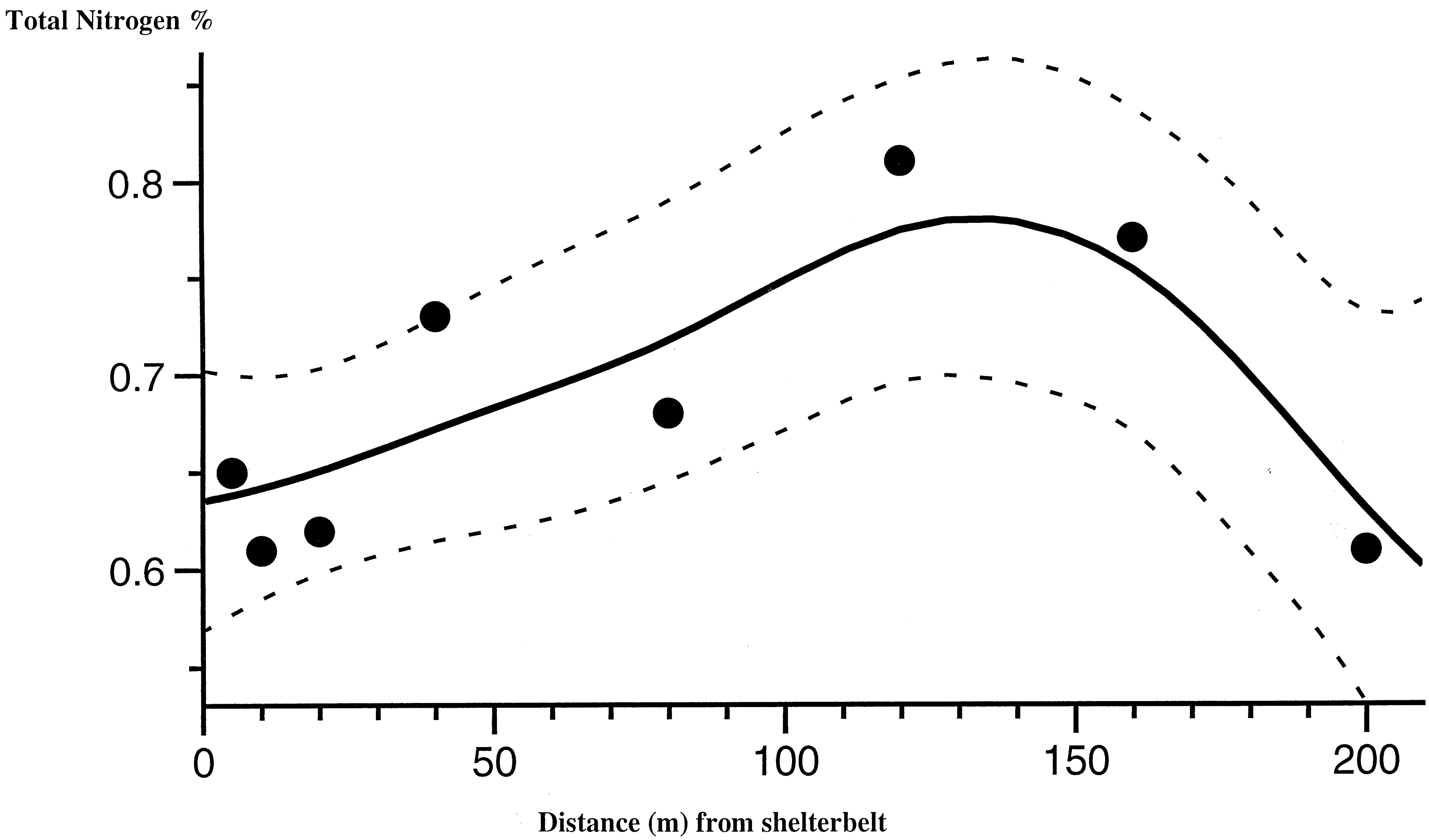
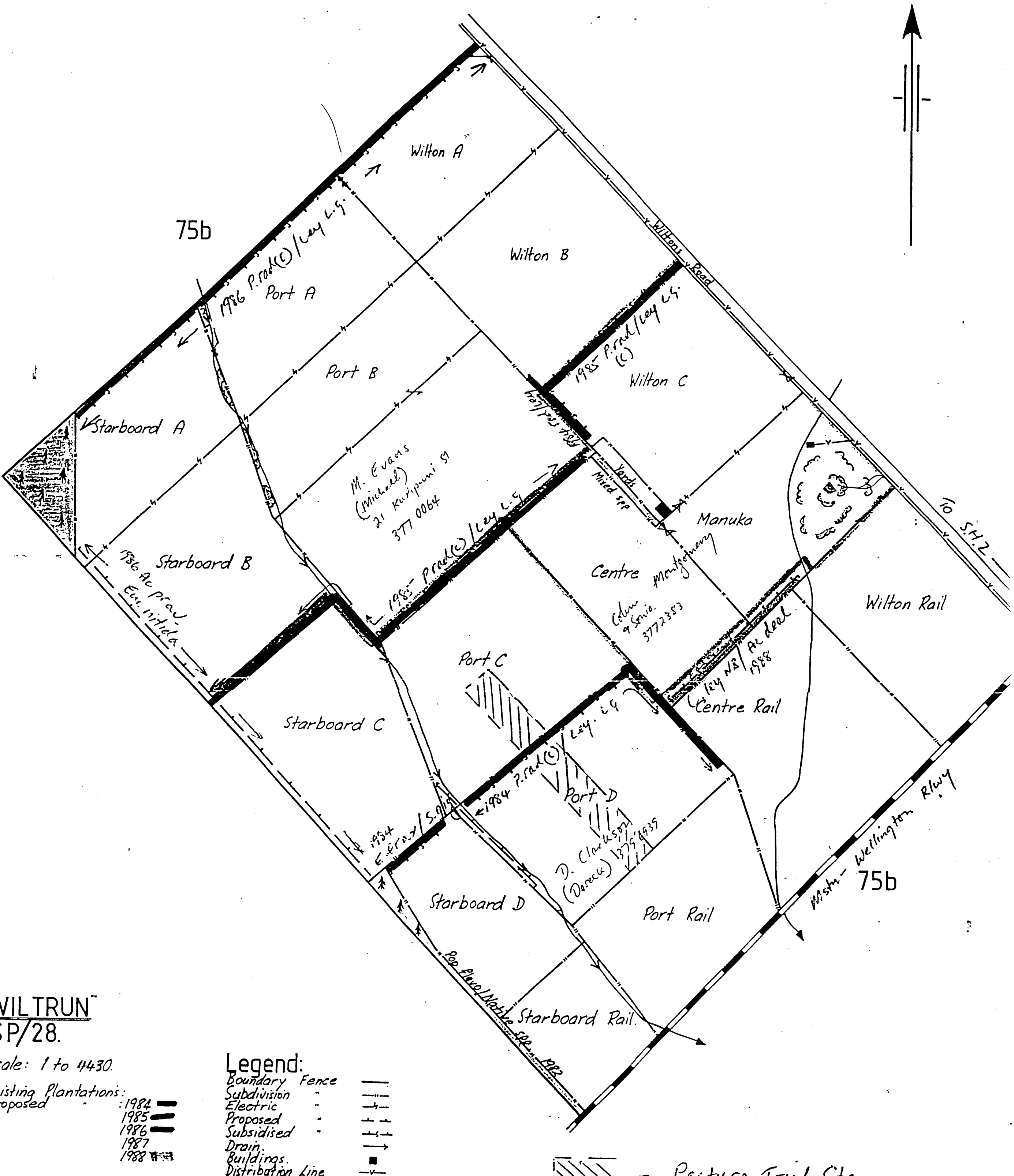


Figure 13: Glasshouse/nursery trial - the effect of distance from shelterbelt on total soil nitrogen



"WILTRUN"
SP/28.

Scale: 1 to 4430.

Existing Plantations: 1984
Proposed " 1985
1986
1987
1988

Legend:

Boundary Fence
Subdivision "
Electric "
Proposed "
Subsidised "
Drain.
Buildings.
Distribution Line
Scrub
Railway

Soil Types:

75b Tauherenikau stony silt loam.

- Pasture Trial Site
P. rad (C) - Radiata 4yr aged cuttings
Ley L.G - Leyland cypress 'Leighton Green'