HYV AND FERTILIZERS--SYNERGY OR SUBSTITUTION. IMPLICATIONS FOR POLICY AND PROSPECTS FOR AGRICULTURAL DEVELOPMENT

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PREFACE

Food production is one of the most complex and many-sided activities of mankind, and involves coordination of biological, technical, environmental and economic factors. To understand the operation of these rather complex systems, it is necessary to make a study of the elements of the system. Kirit Parikh's paper deals with a very important problem: that is the efficiency of fertilizer usage on high-yielding crop varieties as well as the related consequences. The work, as reported in this paper, is a preliminary step toward the development of IIASA's Indian Agricultural Model; its results were used extensively in the IIASA work.

SUMMARY

The conventional wisdom regarding the nature of the yielding varieties (HYV) which have ushered in the "Green Revolution" includes the following beliefs:

1. The HYV's give higher response to fertilizers than the "local" varieties.
2. The HYV's need fertilizer and irrigation for realizing their higher responses.
3. The HYV's respond synergistically to a package of inputs and practices, the most important among the inputs being the three fertilizers--nitrogen, phosphorus and potash--and irrigation.

The policy implications of these beliefs are obvious:

1. It is more efficient to allocate fertilizer to HYV's than to "local" varieties.
2. HYV's should be adopted only when assured water and fertilizers are available.
3. Since inputs act synergistically, it is more efficient to concentrate the developmental efforts in selected areas for promoting intensive agriculture.

It is argued here that the extensive analysis of yield responses to fertilizer that was carried out by Parikh, Srinivasan et al. does not seem to support the conventional wisdom regarding the nature of the HYV technology at least at the low level of inputs used by the Indian farmers and consequently questions the policy implications of that conventional view.

Based on the data from more than 15,000 trials carried out on farmers' fields by the Indian Council of Agricultural Research, it is shown that the yield response functions are such that the best HYV for the zone dominates the local variety and gives higher yield even without fertilizer. It is also found that for some cases the yield response to fertilizer of a local variety is higher than the yield response of the HYV. The paper also argues that it is not easy to reject the hypothesis that the data from the simple fertilizer trials are representative of Indian farms.

The paper also presents in an appendix the estimated yield response of the dominant varieties for 8 major crops of India for different agro-climatic zones along with their plots.

CONTENTS

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Kirit S. Parikh

INTRODUCTION

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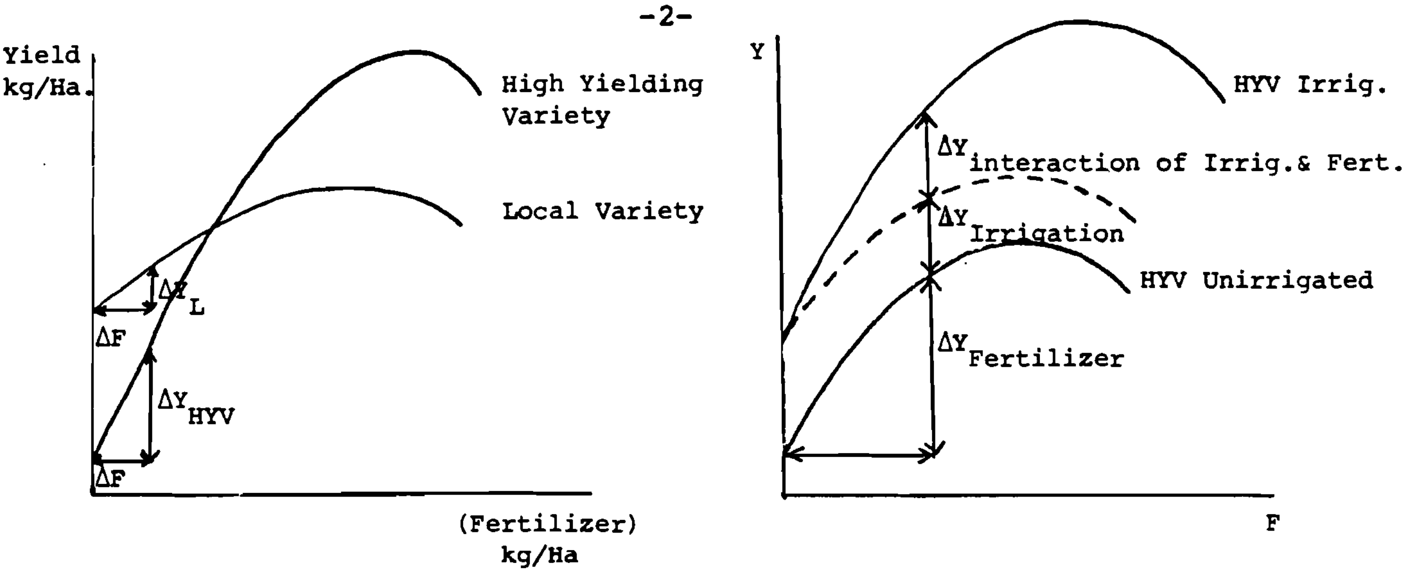
* This paper, with the exception of the Appendix, was published in the "Economic and Political Weekly", Review of Agriculture, March, 1978, Bombay.

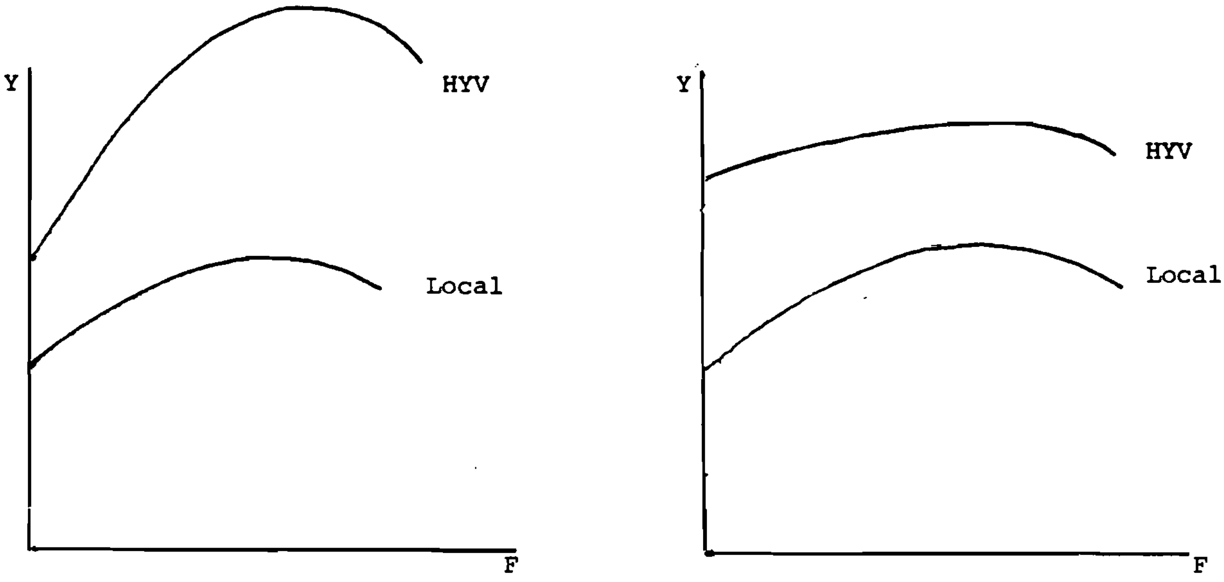


(a)

- o HYV gives higher yields than local only with fertilizer
- o HYV has a higher response $\left(\frac{\Delta Y}{\Delta F} \right)$ to fertilizer

(b)

- o Synergistic response to fertilizers and irrigation $\Delta Y_{(\text{Irrig.\& Fert})} \geq \Delta Y_{\text{Fert.}} + \Delta Y_{\text{Irrig.}}$
- o Better to put fertilizer on irrigated HYV



(c)

- o HYV is dominant and gives higher yield even without fertilizer
- o And, HYV has a higher response to fertilizer

(d)

- o HYV dominates local variety. However local has a higher response to fertilizer
- o Given that both HYV and local are cultivated, fertilizer should be put first on local variety.

Fig. 1 Implications of Different Types of Yield Responses.

However, the extensive analysis of yield responses to fertilizer that was carried out by Parikh, Srinivasan et al. (1974)[1] (henceforth referred to as PS study) does not seem to support the conventional wisdom regarding the nature of the HYV technology at least at the low level of inputs used by Indian farmers and consequently questions the policy implications described above. The implications of different types of yield responses are summarized in Figure 1*, where 1(a) and 1(b) correspond to the conventional view described above. In Figure 1(b), the dotted line shows a line obtained by shifting vertically, by an amount equal to the increase in base yield due to irrigation, the response line for unirrigated HYV. The dotted line thus, represents what would have been the response function for irrigated HYV if there were no interaction between irrigation and fertilizer. From our analysis, however, it is argued that the yield response functions are certainly such that the HYV's are dominant as shown in Figures 1(c) and 1(d); for some cases the slope of the response functions may be more like case 1(d) than like 1(c).

Before turning to the results of our analysis it would be useful to briefly summarize the data collected and the analysis carried out.

THE DATA

The Indian Council of Agricultural Research (ICAR) has had for many years extensive programmes of development of HYV of various crops, as well as for evaluating the yield responses of these and local varieties under different inputs and cultivation practices. For the purpose of evaluating the yield responses to fertilizers, two sets of experiments are particularly important. One set, called the Model Agronomic Experiments (MAE), comprises of experiments carried out on farms of the research stations where complete control is exercised by the researchers. The other set, known as the Simple Fertilizer Trials (SFT), is carried out on cultivators' fields. The main objective of the programme is to determine the fertilizer requirements of the new high yielding varieties and to compare their performance (in cultivators' fields) with the performance of locally improved varieties under different soil and agro-climatic conditions in the country. The SFT's are extensive and cover many different districts and crops.

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*The responses shown in Figure 1 are not the only possible response types--but they cover the points that are being argued in this paper.

Though we had also analysed most of the relevant MAE performed to the year 1969-1970 in research stations, we relied on the results of the Simple Fertilizer Trials (SFT) carried out on farmers' fields up to the year 1970-71 as they were more relevant and extensive. We had data from nearly 31,000 SFT's carried out over the period 1965-66 to 1970-71, of which 15,000 trials were carried out over the years 1968-69 to 1970-71.

For a given crop, the districts for the SFT's are selected randomly (at least in theory). In the field of the selected cultivator, subplots of specified size, (usually around 40 to 50 sq. meters) are laid out, on each of which the cultivator is supposed to sow the given seeds and apply the fertilizer treatments as specified by the researchers. Only the variety and rate of seeds and the quantities of chemical fertilizers are controlled. The cultivator is free to determine all other inputs and practices. The yields in each subplot are separately recorded.

We stratified the data by agro-climatic zones. These zones are shown in appendix Figure A.1. Within a zone, the trials were further stratified merely as irrigated and unirrigated trials because adequate information on the amount of irrigation was not available. For a specific combination of crop variety, agro-climatic zone and water regime, the data were pooled together to estimate the yield response functions separately for different years as well as with pooled data for all the years.

THE ANALYSIS AND THE NATURE OF THE RESPONSE FUNCTIONS

For all the model agronomic experiments and the SFT data for the years 1965-66 to 1969-70, three quadratic response functions were estimated through multiple regression with variables as shown below:

$$Y = f(N, N^2, P, P^2, K, K^2, NP, PK, NK, NPK),$$

$$Y = \text{Yield in kg/ha} \quad .$$

N, P, and K stand for the levels of N, P and K respectively, in kg/ha. NP, PK, NK and NPK stand for the products of the levels of fertilizers applied.

Note that in these regressions in addition to the quadratic terms, interaction terms between N and P, N and K, P and K and N, P and K are also introduced. Positive and significant coefficients or interaction terms imply that the nutrients are more efficient when applied together than when applied separately.

Negative coefficients of the quadratic terms for N^2, P^2, and K^2, would imply diminishing marginal returns to these nutrients, and positive coefficients would imply increasing returns.

In one set of regressions, the intercept representing the base yield was permitted to be different from experiment to experiment to account for variations in soil fertility and culturing practices from farmer to farmer.

In another set of regressions, the effects of these variations are sought to be taken care of by regressing additional yield due to applied nutrients against applied nutrients.

It was observed that the set of response functions which did not distinguish between farmers and in which total yield was regressed against fertilizer applied gave better results than the other two and that the interaction terms were not statistically significant in most of the cases for all the three sets of regressions.

Thus the SFT data do not show any significant interaction among Nitrogenous, Phosphoric and Potassic fertilizers as far as their effects on yield are concerned. The incremental yields due to the three fertilizing nutrients can be taken to be additive.

This is not to suggest that one may not find soils in India where the interaction of the different fertilizers would show dramatic synergistic responses. But our results do indicate that in large parts of the country on the land cultivated by farmers such interaction effects are not significant.

The estimated response functions for paddy and irrigated wheat are shown in Figures 2 and 3 respectively for typical zones. The different curves in a figure refer to different varieties. These figures are typical of almost all the zones and crops for which we had comparable data as can be seen in the appendix where the detailed estimates and plots are given.

Two important observations may be made from these figures:

1. There is one variety which dominates all others in the sense that it gives a higher yield than other varieties at a level of fertilizer use which is the same or lower. This is true even when no fertilizer is applied.
2. The slope of the yield response function of the dominant variety is not necessarily larger than the slopes of other varieties.

These observations imply that a cultivator may be able to get a larger yield from a high yielding variety even without applying any fertilizer.

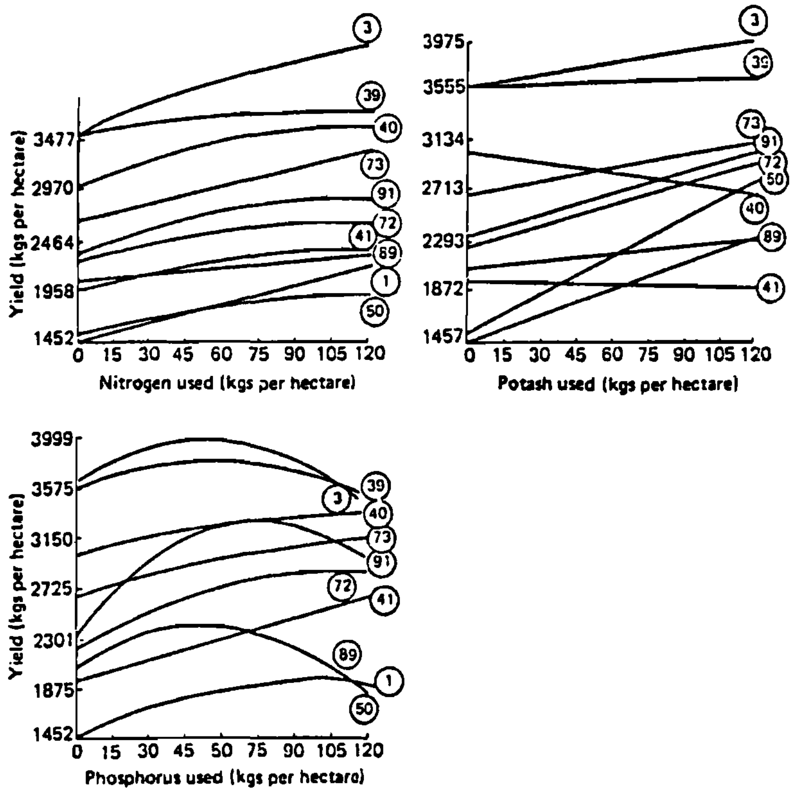

Fig. 2 Yields of different varieties of paddy (Zone-7L+C)

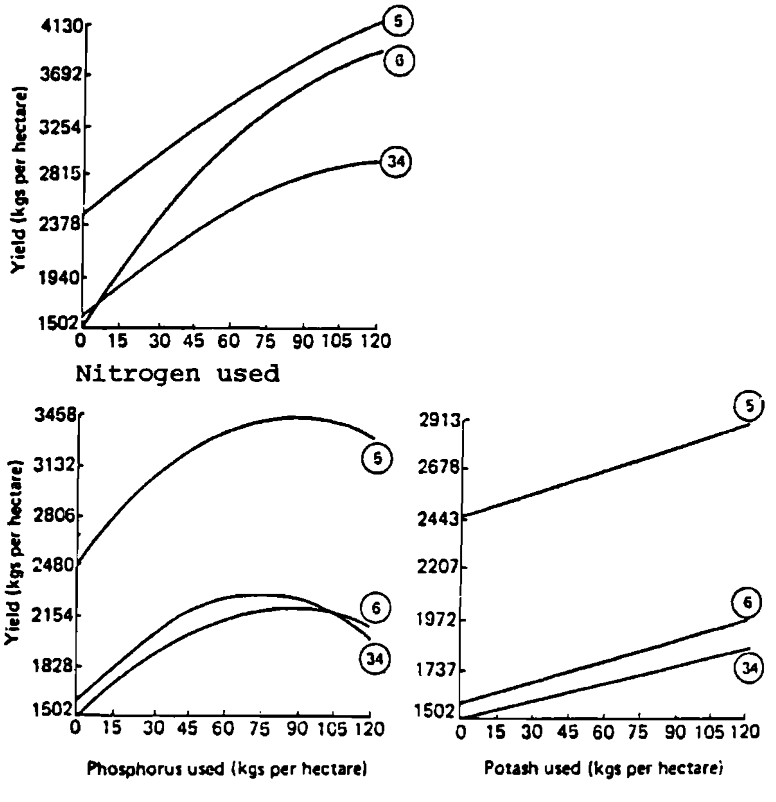

Fig. 3 Yields of different varieties of irrigated wheat (Zone-4A)

Thus a farmer need not be advised to ensure his fertilizer supply before planting HYV seeds.

Typically, however, agronomists react to this conclusion as follows: HYV's give a higher yield and therefore they must take out more nutrients from the soil. Consquently, the yield next year would be lower unless the fertilizers are applied.

A number of comments need to be made on such a reaction.

1. An HYV may give higher yield of grains but may not produce higher bio-mass of the total plant matter. The nutrients removed from the soil should depend on the total plant matter produced.

2. Even if an HYV does deplete the soil when no fertilizer is applied leading to a risk of lower yield in subsequent seasons[2], the new possibility opened up by recognizing that farmers can get the benefits of HYV at least in the first year, even without fertilizers, should be appreciated. It becomes possible for a cultivator to adopt an HYV this year and from the extra revenue of the extra yield buy the fertilizer before the next season.

3. If the agronomists' claim is correct, that HYV depletes the soil unless fertilizer is applied, then the yield response functions required for policy guidance have to be based on trials carried out over a number of seasons on the same plot. Thus the yield response functions obtained from the SFT's are not useful for policy guidance. One wonders why then have we spent so much effort and resources for carrying out these SFT's.

By itself, the fact we have established so far, that the dominant HYV gives a higher yield even without fertilizer than other HYV's is not enough to fully question the view implicit in Figure 1(a) and (b). It may still be possible that a local variety gives a higher yield than the HYV when no fertilizer is applied (Figure 1(a)) or that a complemtarity effect is present.

To examine the issues of complementarity of inputs one would like to compare the yield responses of the best HYV against the best local variety under irrigated and unirrigated cultivation in the same agro-climatic zone. Unfortunately, the data we have analysed do not contain such tests. Nonetheless, a number of pairwise comparisons are possible. Tables 1 and 2 show the base yields for wheat and rice (i.e., yields without any fertilizer applied) for some zones. Also shown in these tables are the "optimum" dosages of fertilizer in the reference case of the PS study.

Table 1. "Optimum"* fertilizer dosages - Kg/Hectare
Wheat - Reference Case.

Zone	Irrigated or not	Variety	Base Yield[a] (Kg/Ha)	"Optimum"* Fertilizer Dosages kg/Ha		
				N	P	K
4A11	Irrigated	HYV(5)	2479	87.5	51.4	0
	Unirrigated	HYV(34)	1402	(120.0)	0	(60.0)
8SM1	Irrigated	HYV	1632	35.3	0	(60.0)
	Unirrigated	HYV	1088	0	8.1	0
3MB12	Irrigated	HYV	1455	38.0	27.6	31.8
	Unirrigated	HYV	555	0	(30.0)	(30.0)
6MB	Irrigated	HYV	1494	(60.0)	29.6	(30.0)
	Unirrigated	HYV	588	0	(25.0)	(25.0)
4RB1	Irrigated	HYV	1641	0	0	0
	Unirrigated	HYV	1448	(120.0)	0	49.6
3A21	Irrigated	HYV	2326	64.7	32.6	29.9
	Unirrigated	HYV	1440	0	25.2	(30.0)
2MB	Irrigated	HYV	1655	0	34.3	0
	"	Local	1044	10.9	29.8	(30.0)
3GB	Irrigated	HYV	2669	0	32.0	0
	"	Local	1842	0	0	18.3
3MB11	Irrigated	HYV	1455	38.0	27.6	31.8
	"	Local	1389	4.4	19.7	25.8
3MB12	Irrigated	HYV	652	0	22.1	0
	"	Local	552	0	15.4	0
3RBRY	Irrigated	HYV	1218	35.1	(30.0)	16.9
	"	Local	1093	0	16.0	21.1
4A2	Irrigated	HYV	1970	36.5	7.6	32.3
	"	Local	1397	0	20.1	23.9
4RB2	Irrigated	HYV	1641	0	0	0
	"	Local	1375	0	0	34.3
5A2	Irrigated	HYV	2049	(60.0)	(30.0)	(30.0)
	Unirrigated	Local	1329	0	17.0	26.6
6BH	Unirrigated	HYV	1233	0	0	(60.0)
	Unirrigated	Local	943	0	0	0

* Having the same marginal physical product, excepting number in ()'s which are bound by the maximum dosages tried in the SFT's and so have higher marginal physical products.

[a] Yield without any fertilizer.

Table 2. "Optimum"* fertilizer dosages - kg/Hectare

Paddy - Reference Case

Zone	Irrigated Unirrigated	Variety HYV/Local	Base Yield@ Kg/Hectare	"Optimum"* Fertilizer Dosages Kg/Hectare of nutrients		
				N	P	K
4A3	Irrigated	HYV	2554	(60)	(30)	(30)
	Irrigated	Local	1886	(60)	(30)	(30)
4MB 1	Irrigated	HYV	3097	57.6	25.3	33.4
	Irrigated	Local	2413	(120)	(60)	0
4A2	Irrigated	HYV	1915	(120)	(60)	0
	Irrigated	Local	1548	(120)	44.9	57.1
7LCA	Unirrigated	HYV	3759	(120)	(60)	36.2
	Unirrigated	Local	1524	0	0	(60)
5DB	Unirrigated	HYV	1377	0	0	(30)
	Unirrigated	Local	898	0	(30)	(30)

* Having the same marginal physical product, excepting numbers in ()'s which are bound by the maximum dosages tried in the SFT's and so have higher marginal physical products.

@ Yield without any fertilizer

The reference case involved computation of the minimum total value of fertilizer (N, P, and K) required to meet the output targets of the five year plan given the relative prices of the fertilizers and the area under HYV as per the plan targets. (For details see ref.1).

At these dosages all the varieties give the same marginal physical product for a unit of fertilizer, excepting when the dosage of fertilizer is at the upper limit of the permitted dosage, in which case the marginal physical product is higher. Limits on fertilizer dosages were imposed so as not to extrapolate responses outside the range of dosages applied in the SFT's.

The nine zones for wheat and the five zones of paddy for which responses for HYV and local varieties are available from SFT's, the base yield of the HYV is higher than the yield of the local variety in the same zone. This is true also of the unirrigated cultivation for which responses are available for three zones. Thus the HYV does dominate the local variety even at zero fertilizer level.

The base yields of the irrigated HYV's of wheat are also higher when compared with the base yields of the unirrigated HYV's for the 6 zones in Table 1 for which comparable responses are available from SFT's.

However, whether the improvement in the yield of irrigated HYV over yield of unirrigated HYV is more than the improvement in the yield of irrigated local variety over yield of unirrigated local variety cannot be established (or disestablished) for want of comparable data.

A comparison of the "optimal" dosages in Tables 1 and 2 can give us some idea about the extent of complementarity between fertilizer and irrigation and between HYV and fertilizers.

If fertilizers and irrigation are complementary inputs for HYV's then the "optimal" dosages of fertilizers for irrigated HYV should be higher than those for unirrigated HYV. The first six zones in Table 1 do not show this to be the case unambiguously. For nitrogen, the yield response is better for unirrigated HYV for 2 out of 6 cases. Both for P_2O_5 and K_2O the unirrigated HYV response is better for 2 cases and nearly equal for 3 cases out of a total of 6 cases.

If fertilizers and HYV's are complementary, then we could expect to see that "optimal" fertilizer dosages would be higher for HYV's than for the local varieties. We see that of the 14 zones (9 for wheat and 5 for paddy) giving 42 fertilizer dosages, HYV optimal dosages are larger for 18 cases, smaller for 11 cases, and the same as that for the local varieties for 13 cases. Thus once again we see that the complementarity between the HYV and fertilizer cannot be considered to be very dominant.

The policy implications are that fertilizer need not necessarily be concentrated either on irrigated land or on HYV's. Fertilizer allocation ought to based on an analysis of local conditions and responses of the available varieties. It should not be guided by general principles of synergy or intensive agricultural development.

HOW RELIABLE ARE SFT RESULTS?

It has been suggested many times that the SFT responses are better than that which could be expected under conditions of "mass applications"[3]. The statement implies that in a given zone the cultivators who on their own grow a given high yielding variety for a given level of fertilizers get a lower yield than the yield obtained by the cultivators under the SFT programme growing the same variety for the same level of fertilizers. It is not clear on what basis such a suggestion is made. I do not know of any systematic study which has collected the type of data required for such a comparison[4]. Nonetheless, one can advance two possible explanations for such a belief. Apart from the point discussed above, namely that of a possible loss of soil fertility when HYV is cultivated without fertilizers, SFT responses may give better results than the average responses in the zone if the SFT farmers and farms were not representative of the zone as a whole.

In the absence of data perhaps the gross "scale factor" adjustment (see below) made in the PS study may be as good a way as any to evaluate in broad terms the issue of how representative are the crop yield response functions obtained from the SFT data.

The model in the PS study calculates the optimum requirements of fertilizers to produce prescribed amounts of output, given the areas allocated to the crop in different zones and given the yield response functions in each of the zones.

In order to do so, the PS model was applied to a past year's data to predict the fertilizer required and to compare the predicted data against the actual values.

For this purpose, the year 1970-71 was selected as the latest year which was not unusually bad or good and for which data were available for the statewise total, irrigated and unirrigated areas devoted to the HYV and local varieties of different crops and statewise production of the crops as well as statewise total consumption of N, P_2O_5 and K_2O. 1970-71 was also one of the years on the SFT data of which our response functions are estimated.

Not having data on cropwise consumption of fertilizers, all the yield response curves were shifted up or down together by the same percentage so that the amount of fertilizer required equalled the amount actually used in 1970-71 and the estimated production was equal to the actual.

The ratio of the final adjusted base yield to the base yield estimated from SFT data was called the "scale factor" for the state.

It should be noted that the "scale factor" merely shifts the yield response up or down without affecting the shape of the response curve. In other words the marginal yields of fertilizers are not affected. There is some evidence to suggest that the various agricultural practices, the effects of which are not explicitly taken into account in our estimated response function affect mainly the base yields[5].

The scale factors obtained are shown in Table 3:

Table 3. The "scale factors".

State Name	Scale factor estimated
Andhra Pradesh	.98650
Assam	.66756
Bihar	.68572
Gujarat	1.19980
Himachal Pradesh	1.13887
Jammu and Kashmir	1.08990
Kerala*	
Tamilnadu	.97697
Karnataka	1.19980
Maharashtra	.75000
Madhya Pradesh	1.31250
Haryana	1.07656
Orissa	.82500
Punjab	.90015
Rajasthan	1.19980
Uttar Pradesh	.86250
West Bengal	.67188

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*Since large parts of fertilizer consumption in Kerala is for plantation for which separate consumption data was not available to us, we have not attempted to estimate scale factor for the state.

A scale factor of 1.0 implies that the yield responses obtained from the SFT data are equal to the average responses of the state. A scale factor larger (smaller) than 1.0 implies that the SFT yields are smaller (larger) than the state averages.

Of the 16 states for which we had calculated the scale factors 7 are greater than 1.0, and 2 more are almost equal to 1.0. The median value is around 0.98 and the average is 0.96.

One cannot thus rule out that the SFT responses are reasonably representative and that they do not have any particular optimistic bias.

Admittedly, the scale factor adjustment has involved a number of assumptions, and one may not accept this evidence as conclusive for the representativeness of the SFT results. Even then it should be emphasized that there is no evidence whatsoever on which one can say that SFT results are not reproducible on a large scale.

PROSPECT FOR AGRICULTURAL DEVELOPMENT

A simple projection based on the SFT data without using any scale factors can indicate the potential for growth of output in Indian Agriculture.

The production potential and the fertilizer required have been worked out[6] assuming that:

1. all farmers would adopt the dominant variety;
2. the yields in zones in which no SFT's have been carried out would be the average yield in the zones in which SFT's are carried out;
3. the expansion of area under cultivation and irrigation is restricted to the fifth five-year plan targets,(i.e., targets to be achieved by March, 1979).
4. the fertilizer dosages cannot exceed the maximum levels tried in the SFT's;
5. the cropping pattern in an agro-climatic zone remains the same as for the latest years for which data were available, which was for 1967-68 for most of the zones.

These projections are given in Table 4.

Table 4. Prospects for Agricultural Output (in million tonnes).

Crop	Actual Prod. for 1974-75*	Production Potential	Input Requirements of Nitrogen	Phosphorus	Potash
Rice	40.2	168	5.05	2.47	2.43
Jowar	10.2	38	1.00	0.60	0.50
Bajra	3.2	24	1.00	0.19	0.47
Maize	5.7	22	0.61	0.28	0.32
Wheat	24.2	73	1.88	0.88	0.82
Cotton	3.6	11	0.67	0.29	0.42
Groundnut	5	12	0.24	0.33	0.27
Gram	4	12	0.26	0.50	0.33

*Data on cropwise consumption of fertilizer are not available for 1974-75. However, total fertilizer consumption (not just these 8 crops) in the country was 1.77, 0.47 and 0.34 million tonnes of N, P_2O_5, and K_2O respectively.

Clearly the technical production potential is very large, and the fertilizer requirements are also moderate.

Of the assumptions made above, two are more important in terms of the policy actions required for the realization of this potential. These are the adoption of the dominant (HYV) varieties by the farmer, and evolution and testing of HYV's (for the agro-climatic zones for which such varieties have not been tested in the SFT's till the end of 1970-71. Both these require much greater efforts in research and extension than have been made till now, but ought not to pose any difficulties in mounting these efforts, particularly once it is recognized that the new technology provides significant growth potential through an extensive rather than intensive development.

It seems to me that quite a bit of this potential should be realizeable without significant structural changes in the ownership pattern or tenancy structure. This is not to say that reforms in the latter are not desirable or that they may not even increase the adoption rate of new technology. It is merely to emphasize that growth is possible without requiring as preconditions for growth what today seems to be politically improbable structural reforms.

NOTES

1. Kirit S. Parikh, T. N. Srinivasan et al. (Dec. 1974) Optimum Requirements of Fertilizers for the Fifth Plan Period. New Delhi: Indian Statistical Institute and The Fertilizer Association of India.

2. This is a bit surprising as it is usually claimed that nitrogen is not carried over in the soil from one season to another, and nitrogen is the relatively more important nutrient for Indian soils.

3. A. Vaidyanathan. (Dec. 17, 1977) Constraints on Growth and Policy Options Reply. Economic and Political Weekly 13(51).

4. The NCAER study (Sept. 1974) Fertilizer Use on Selected Crops in India, New Delhi: National Council of Applied Economic Research and The Fertilizer Association of India, is not quite adequate for this purpose, as the fertilizer dosages are reported not statewise but on all India basis and the varieties are not identified in their reports.

   However, the results do show that farmers do use fertilizers on irrigated as well as unirrigated and on HYV as well as on local variety cultivations, and thus do recognize the various substitution possibilities.

5. H. van Keulen. (1977) Nitrogen Requirements of Rice with Special Reference to Java. Contributions (30). Bognor (Indonesia): Central Research Institute for Agriculture. He argues that the relationship between N-uptake by the plant and N-fertilization given to the soil is linear with some N-uptake even at zero level of N-fertilization and that this intercept represents the inherent soil fertility and is a function of soil characteristics, environmental conditions, and the history of the field, particularly previous crop, fertilizer application and management practices.

6. Kirit S. Parikh. (1976) India in 2001. Population, Resources and Environment, edited by Coale, Ansley. New York: Macmillan.

APPENDIX: YIELD RESPONSES OF DIFFERENT CROP VARIETIES IN DIFFERENT AGRO-CLIMATIC ZONES

The yield response functions estimated from the simple fertilizer trials, for the different varieties in a zone, were classified into five separate groups as follows:

Group Code	Description
1	Irrigated HYV
2	Unirrigated HYV
3	Dry Farming Variety
4	Irrigated "Local" Variety
5	Unirrigated "Local" Variety

In each of these groups, the dominant varieties were identified. In this appendix, we present the yield response functions and their plots for those zones for which varieties from two or more of the above five groups were tried out.

The agro-climatic zones are shown in Figure A.1.

The estimated response functions are shown in the tables A.1 to A.9. Since the interaction terms between Nitrogenous, Potassic and Phosphatic fertilizers were found to be insignificant in most of the regressions, it is possible to plot the yield response functions separately for the three nutrients. These plots are given in Figures A.2 to A.10.

It should be noted that in the plots for dosages of fertilizers that exceed the maximum dosage tried in the experiments, the yields are shown to be constant at the value of the yield corresponding to the maximum dosage of fertilizer.

The fertilizers are measured in terms of nutrients.

Figure A.1 Agro-Climatic Zones of India

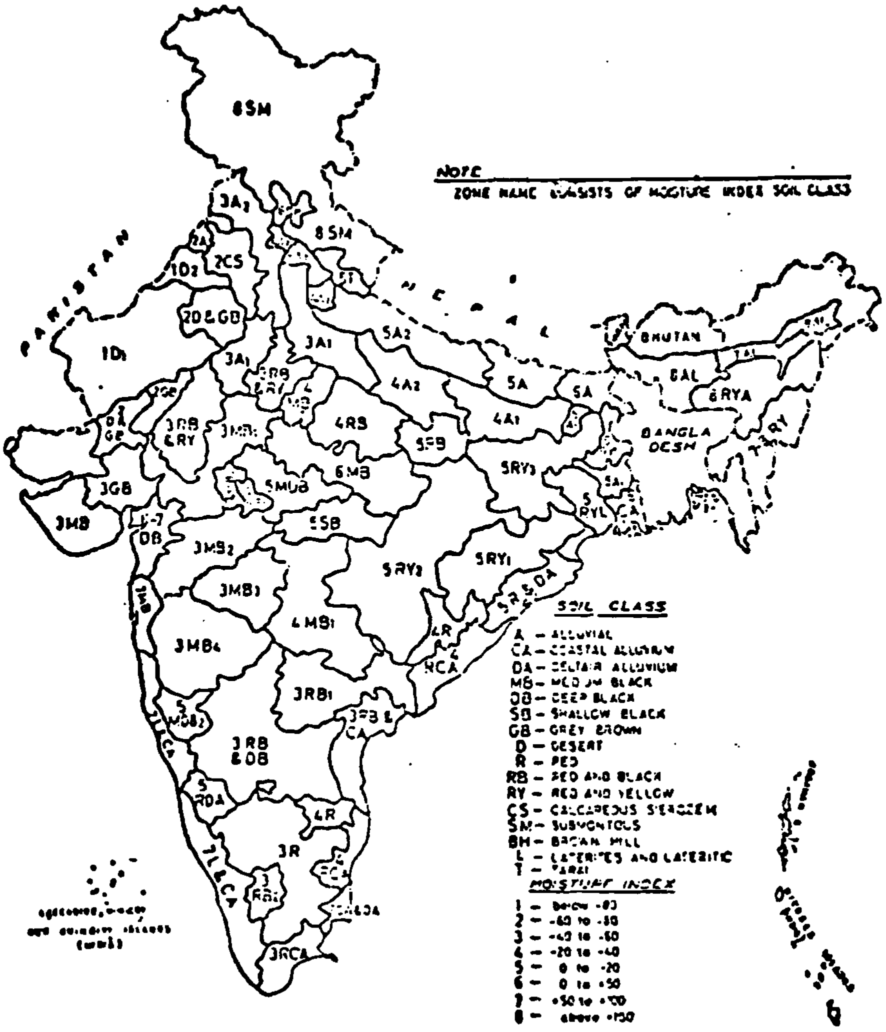

Figure A.2 **Yield Response of Winter Paddy**

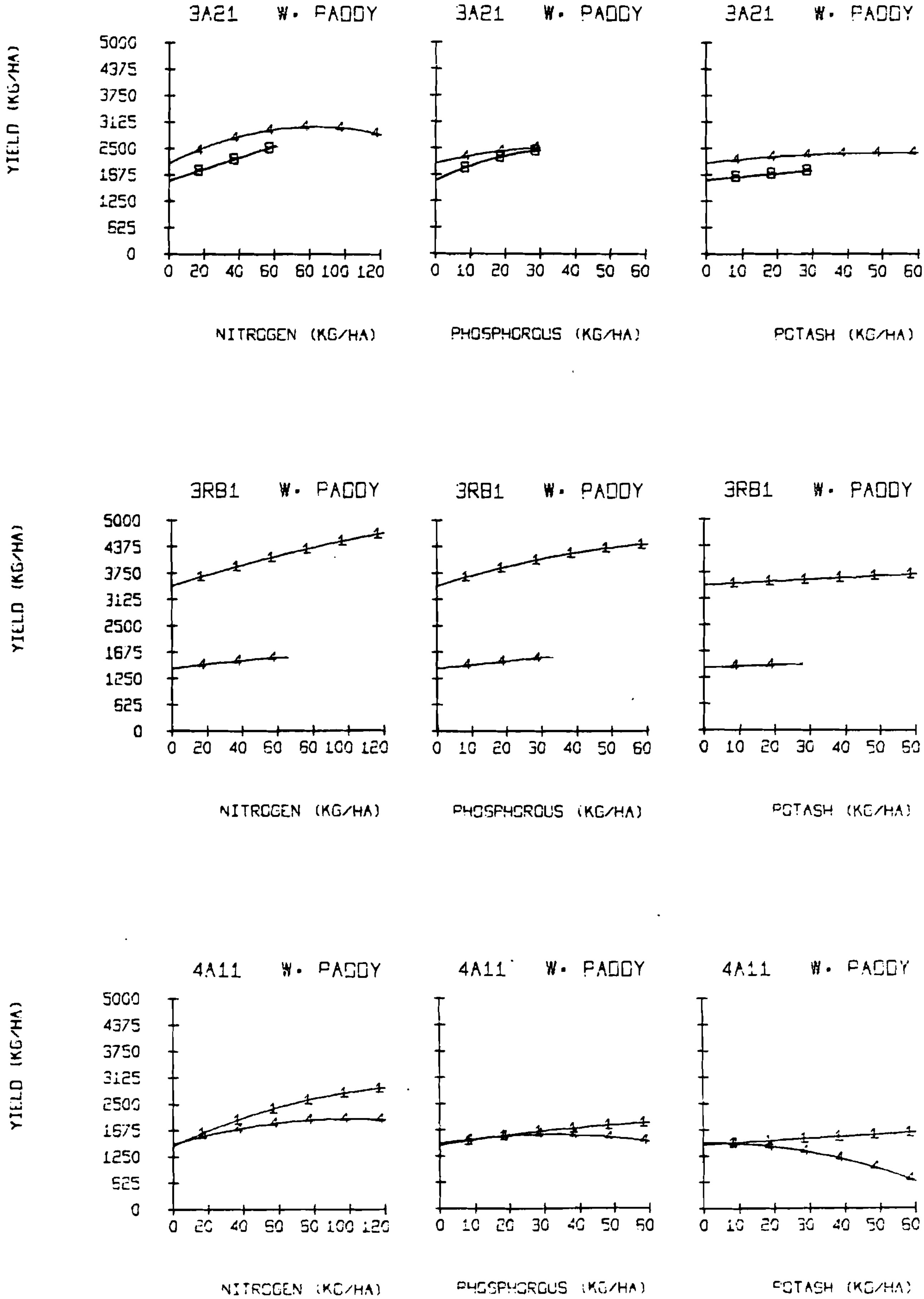

Figure A.2 (Contd)

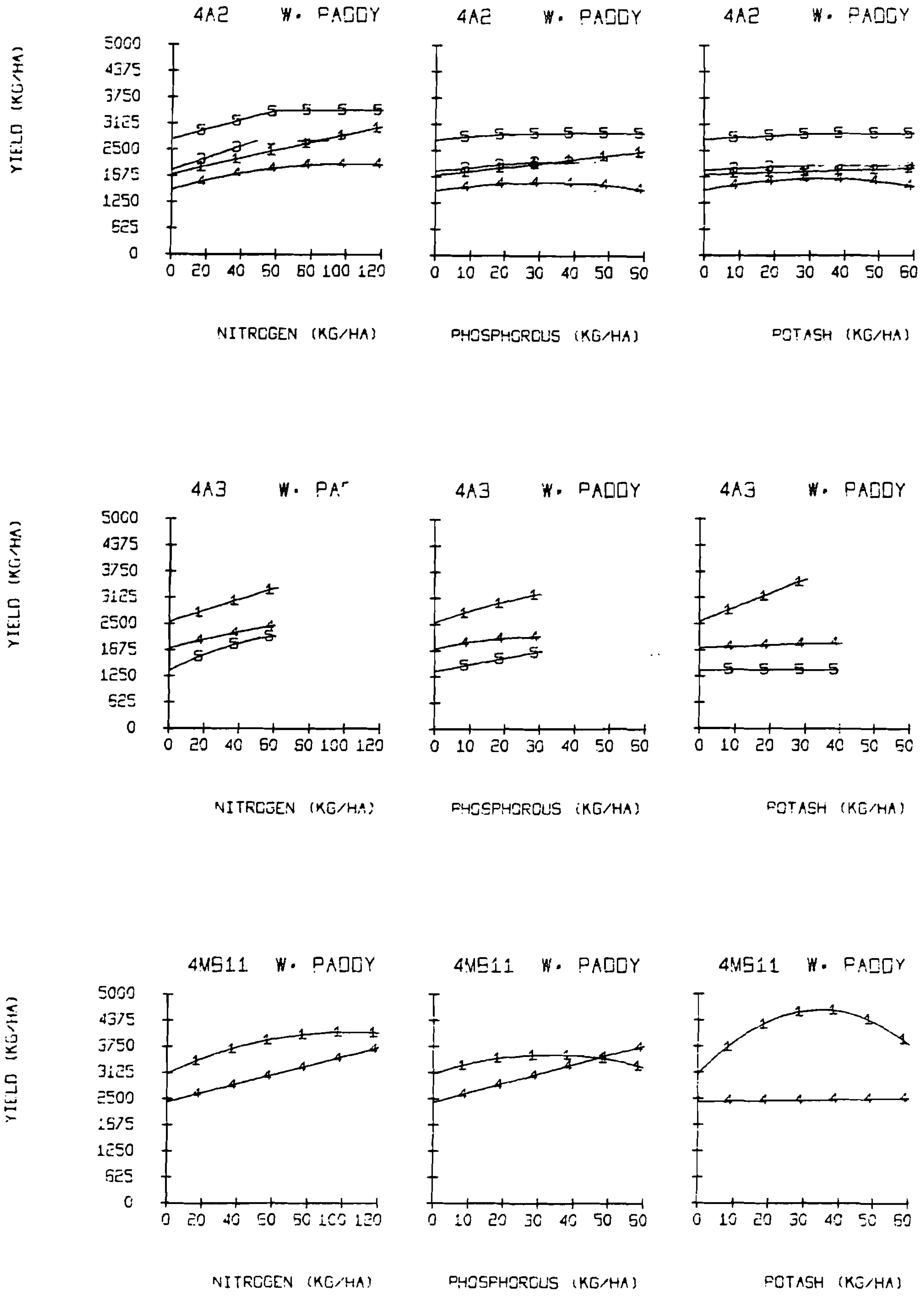

Figure A.2 (Contd)

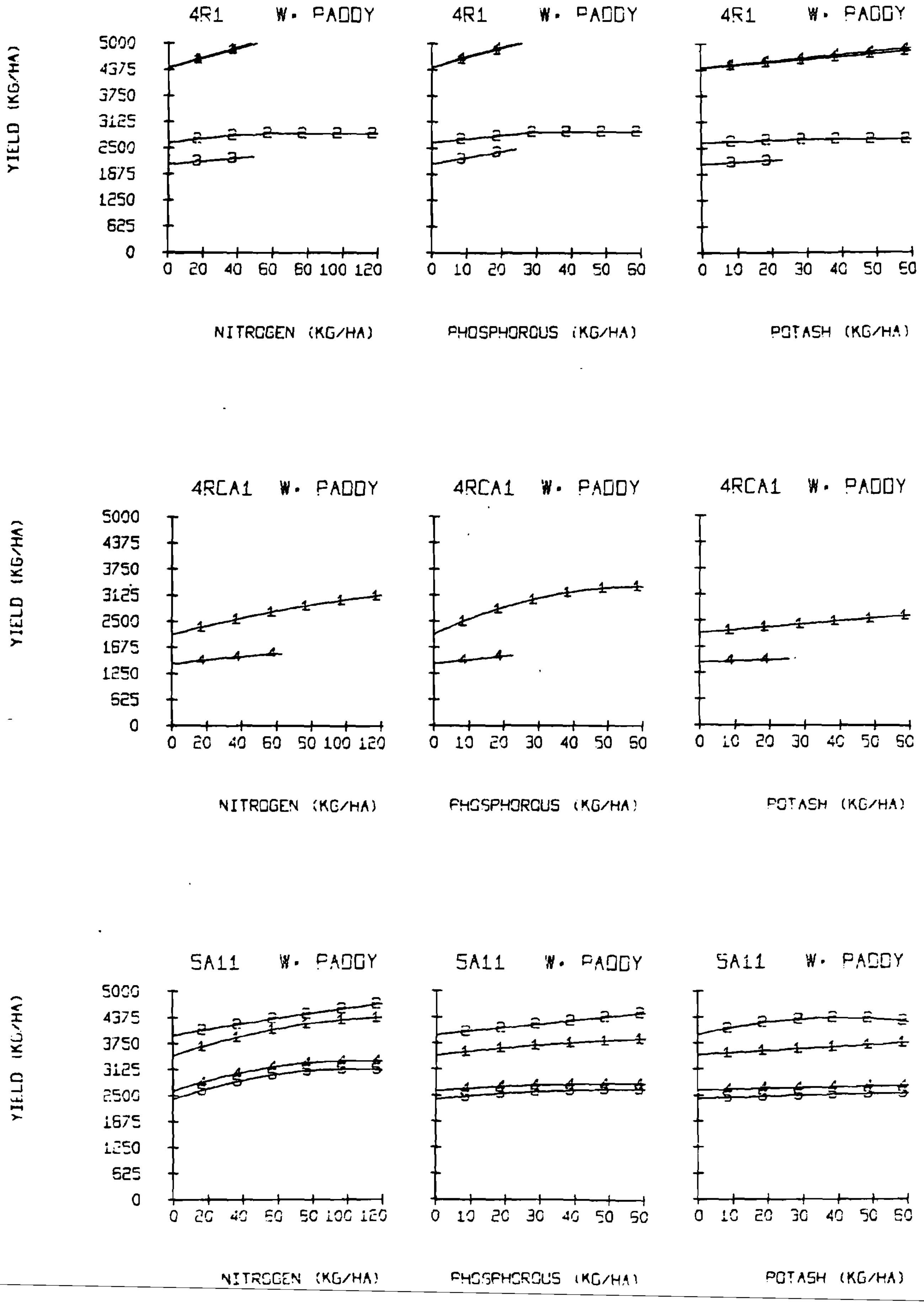

Figure A.2 (Contd)

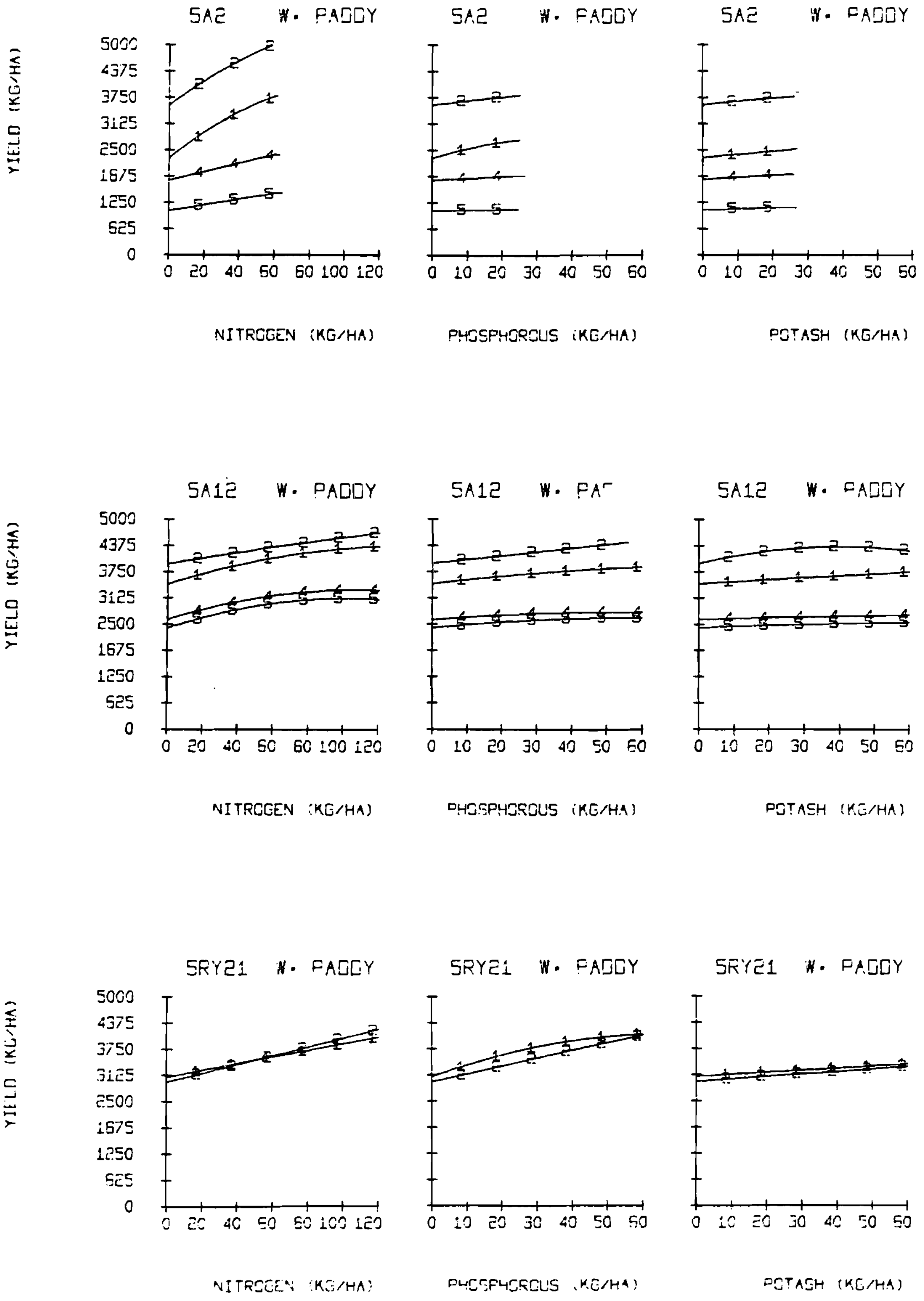

Figure A.2 (contd)

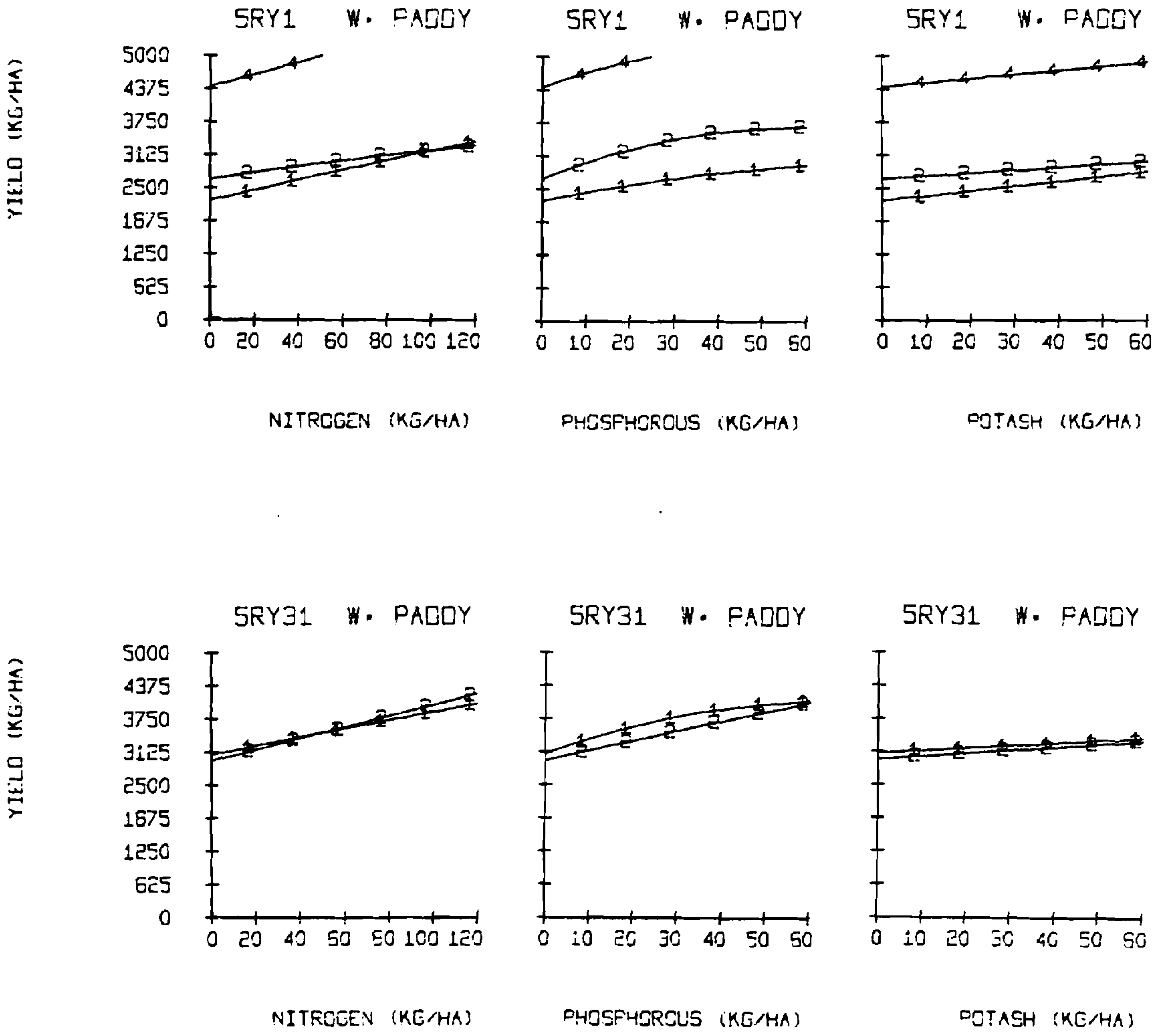

Figure A.2 (contd)

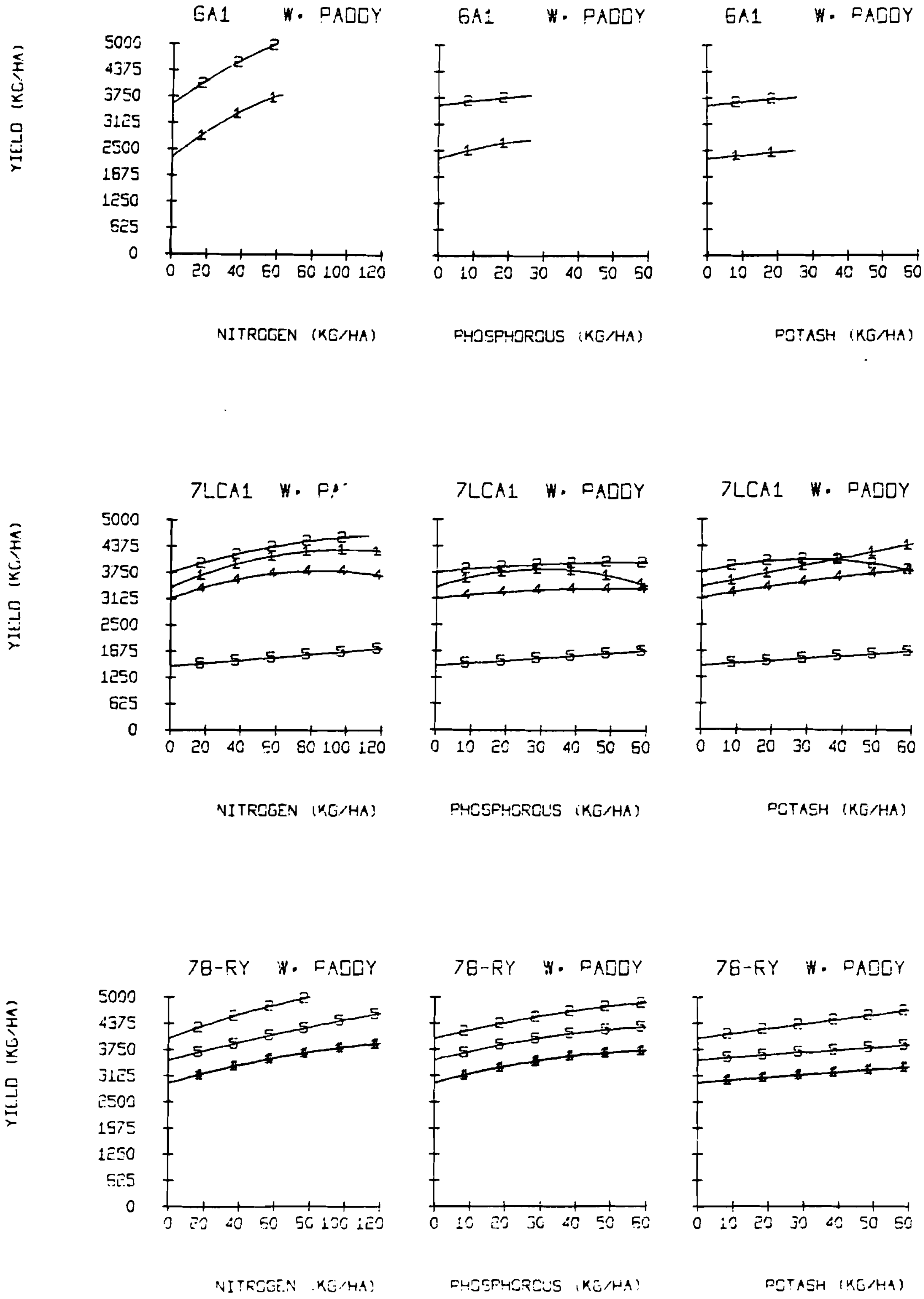

Figure A.2 (contd)

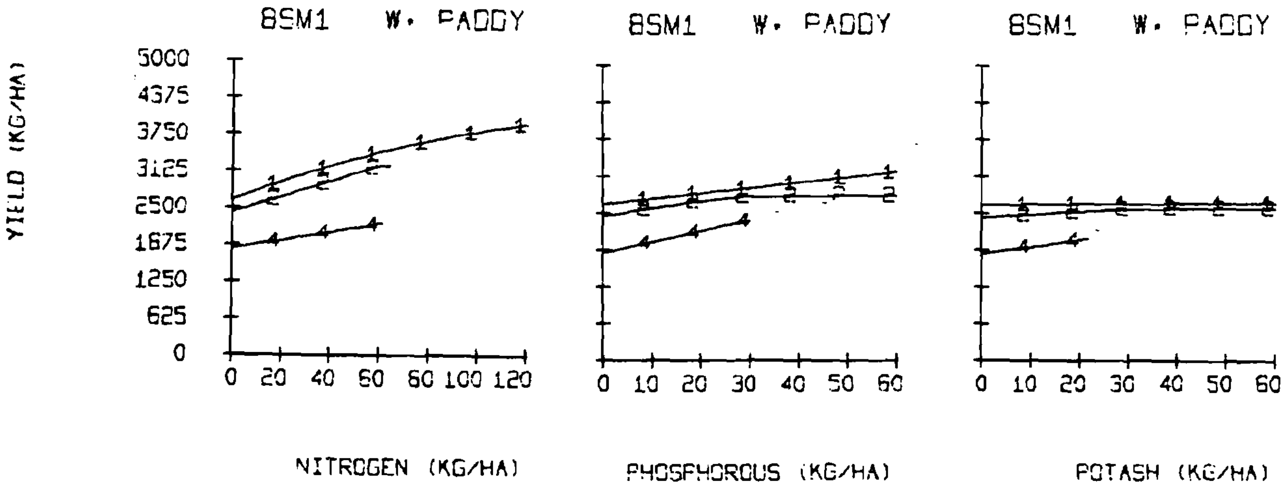

Figure A.3 **Yield Response of Autumn Paddy**

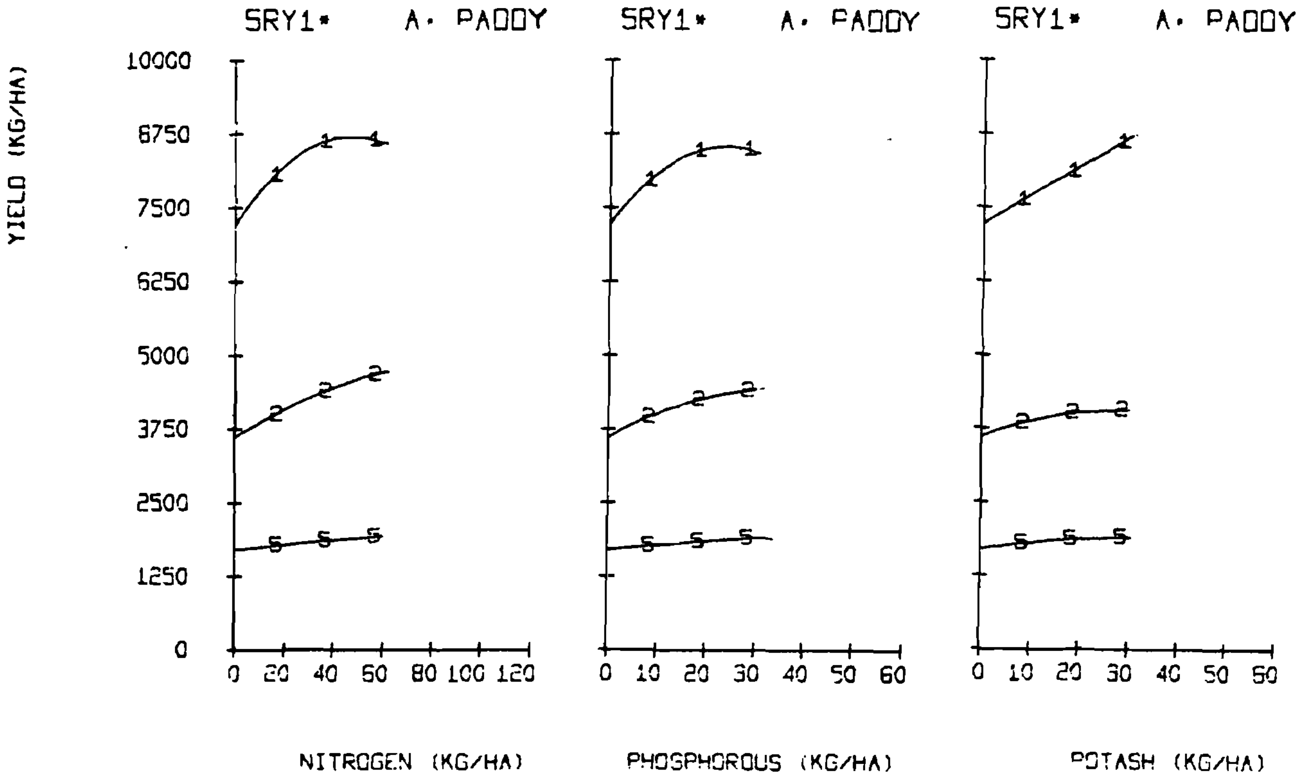

Figure A.3 (contd)

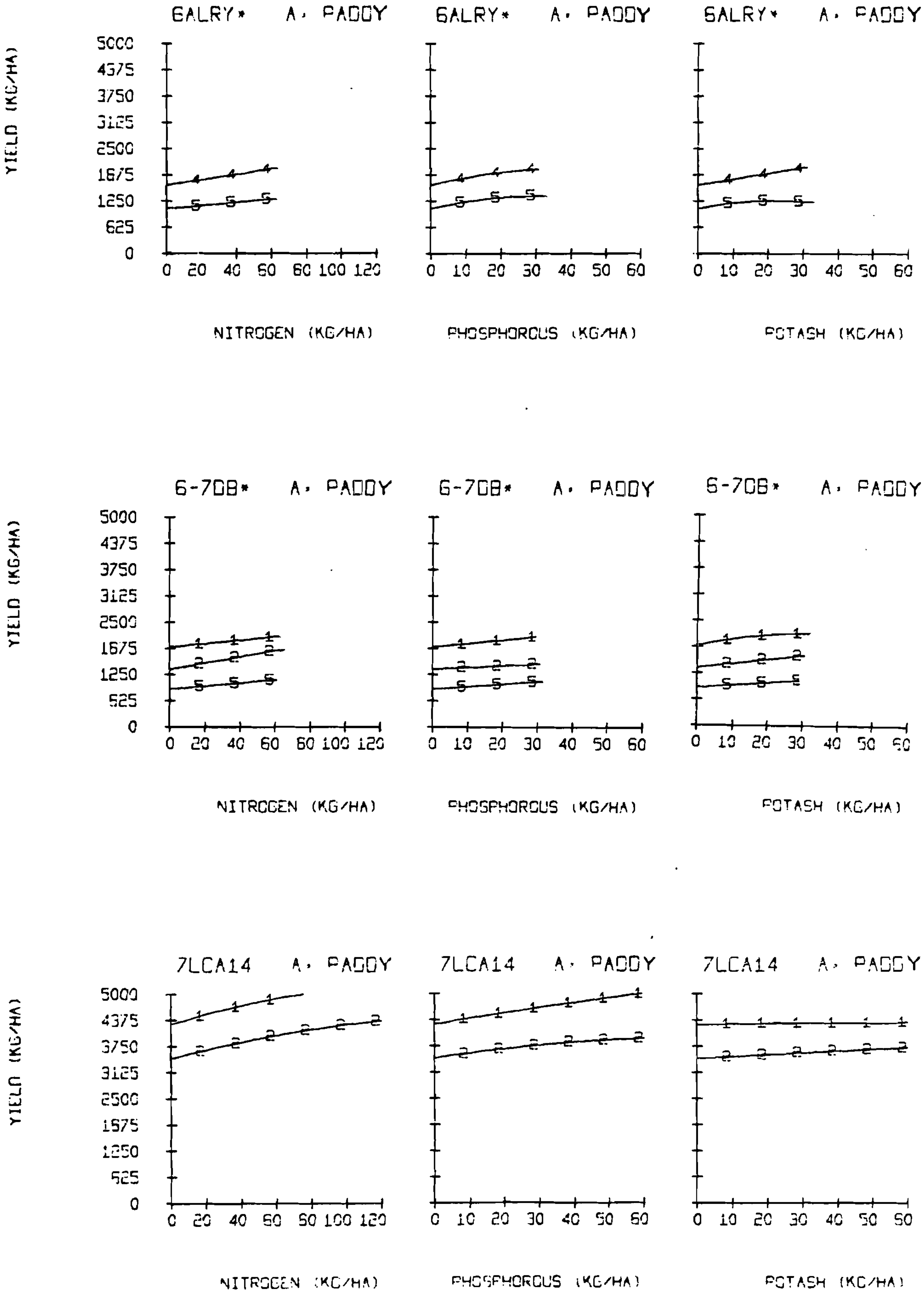

Figure A.4 **Yield Responses of Wheat**

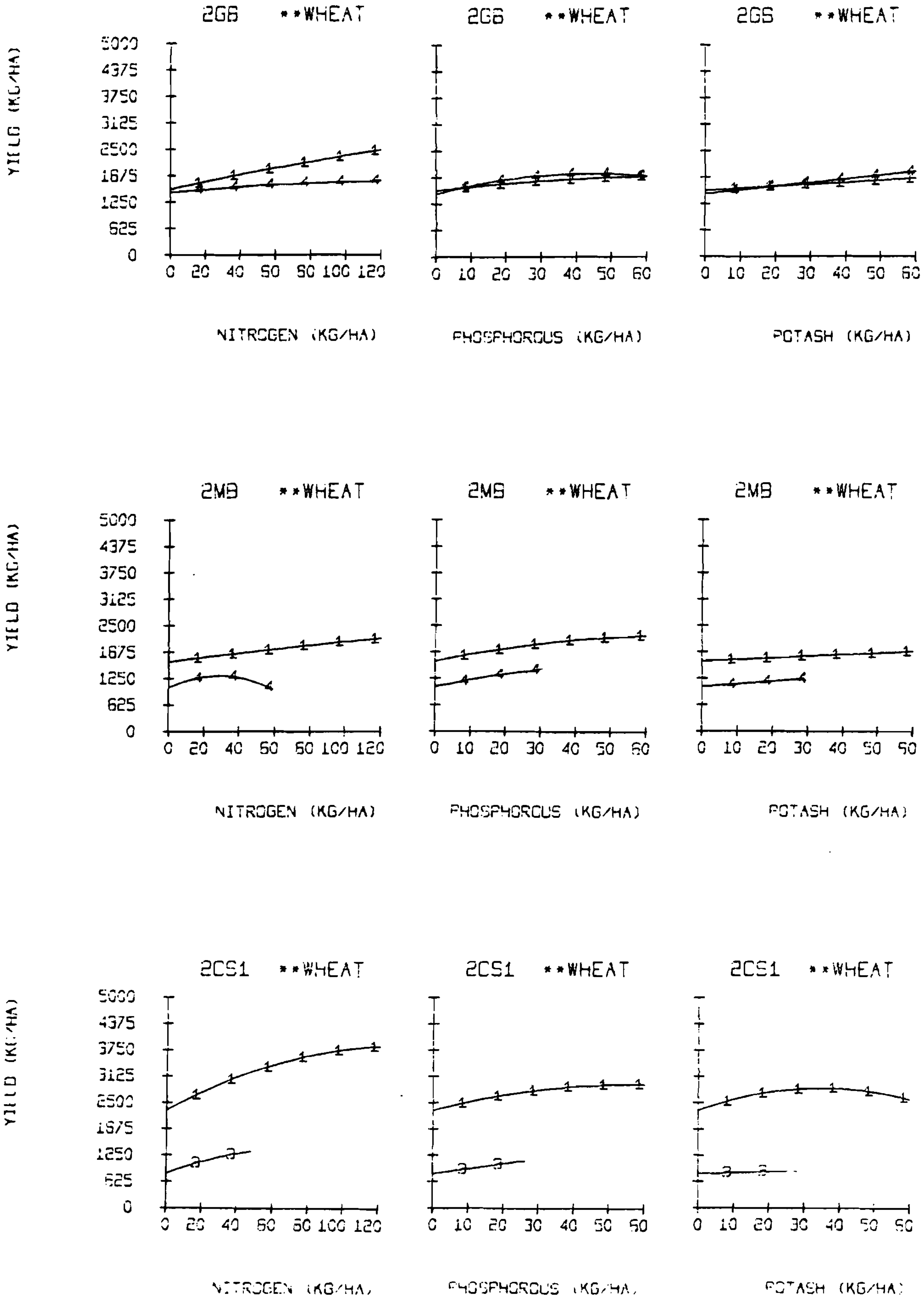

Figure A.4 (contd)

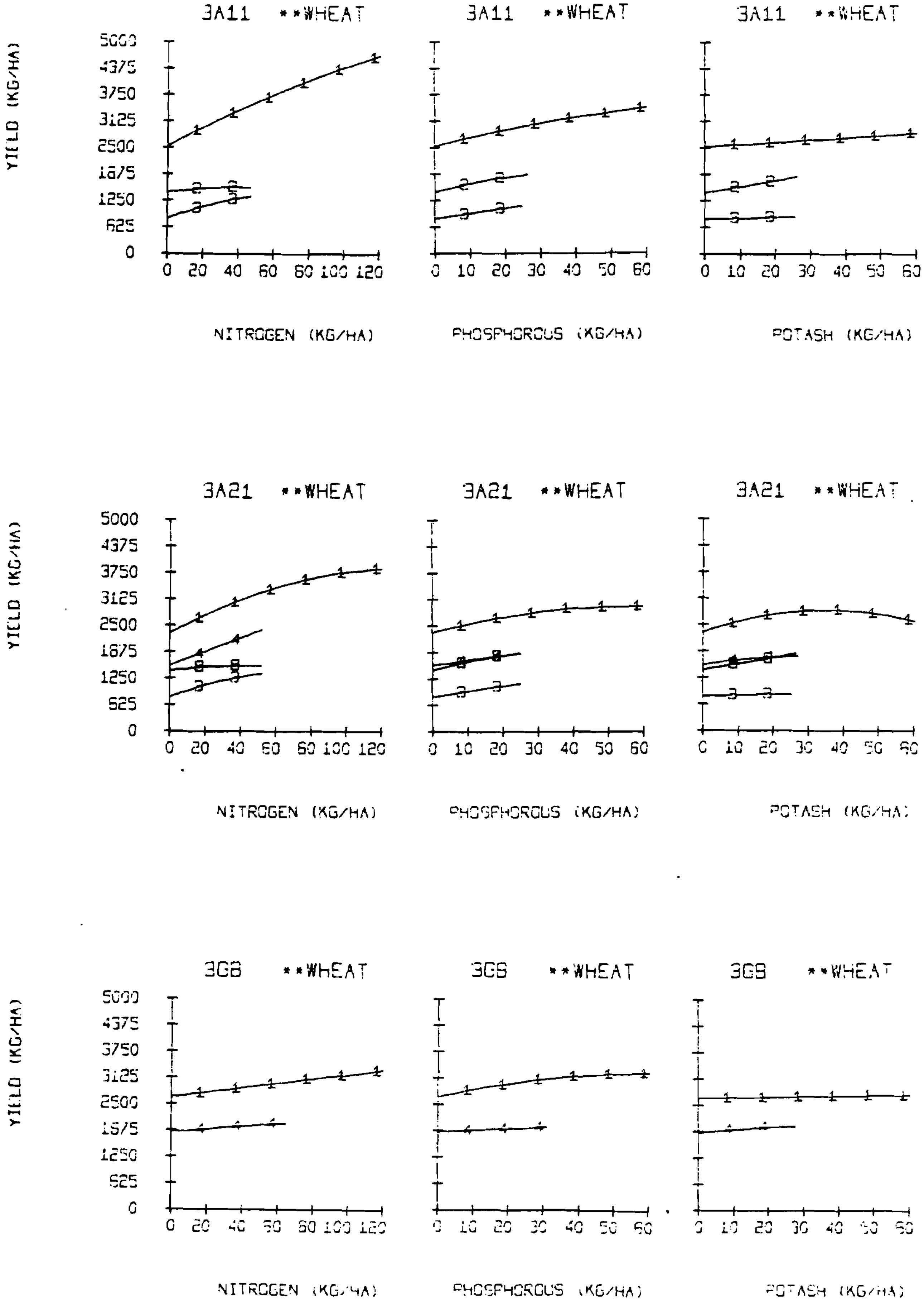

Figure A.4 (contd)

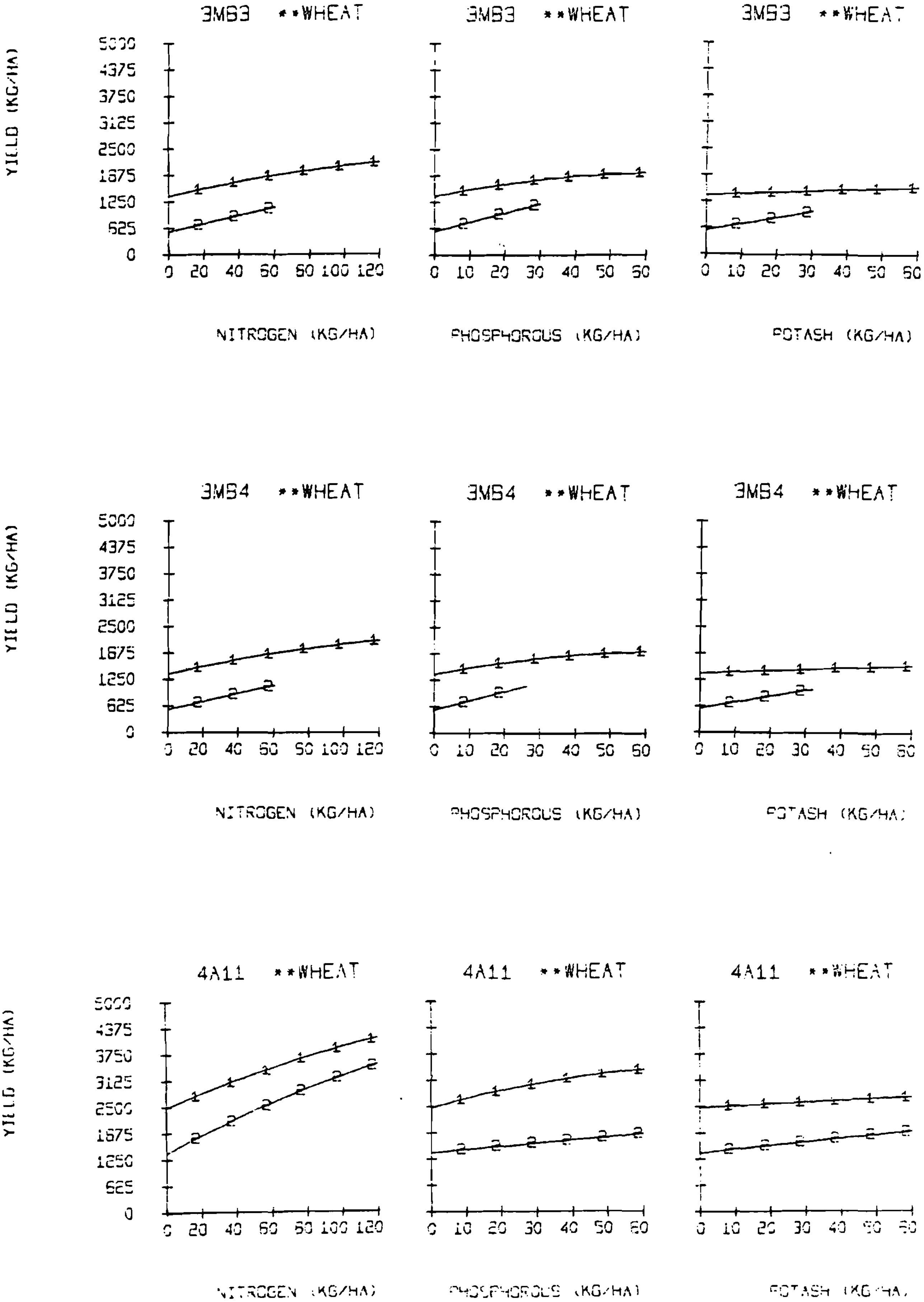

Figure A.4 (contd)

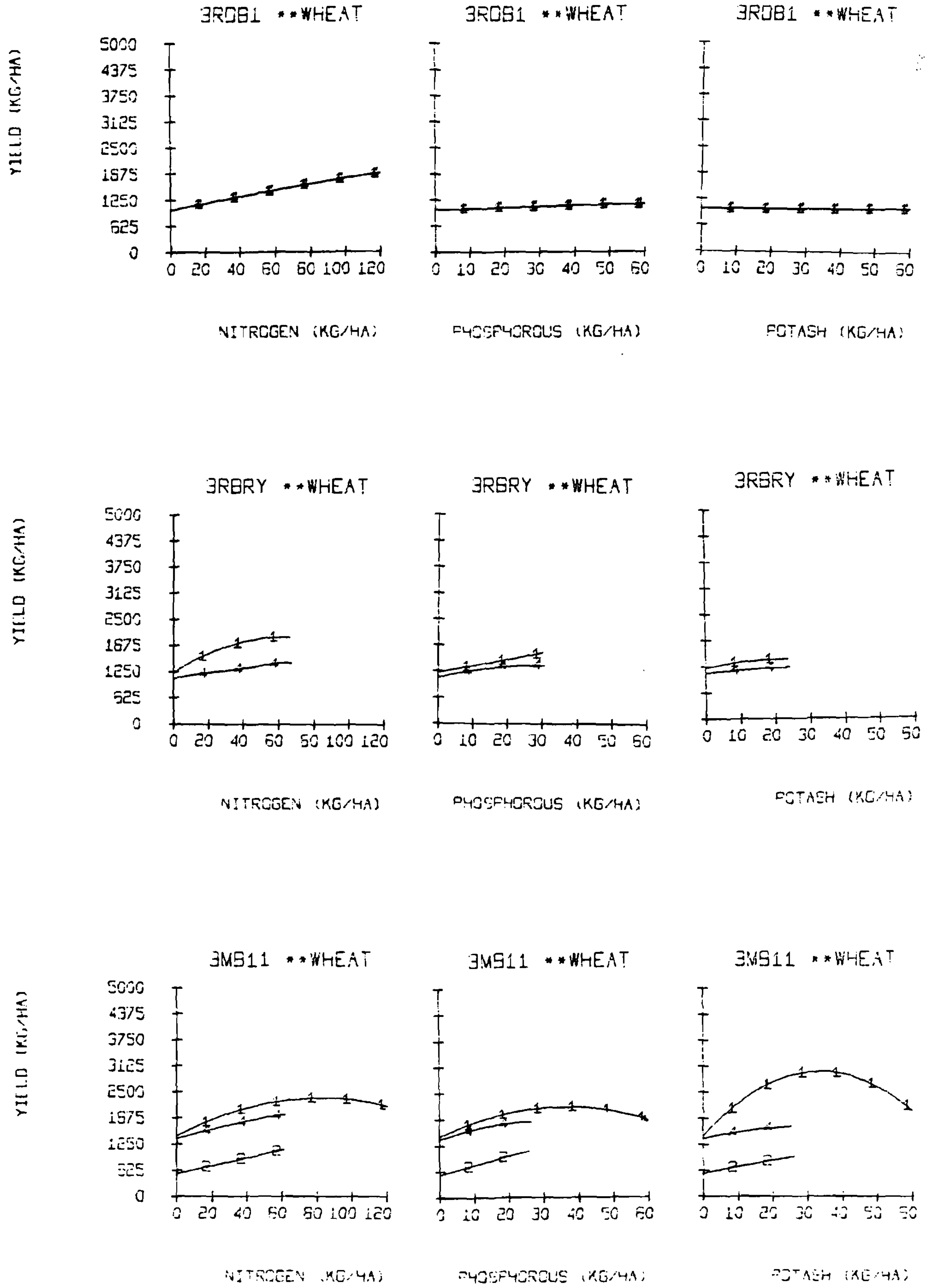

Figure A.4 (contd)

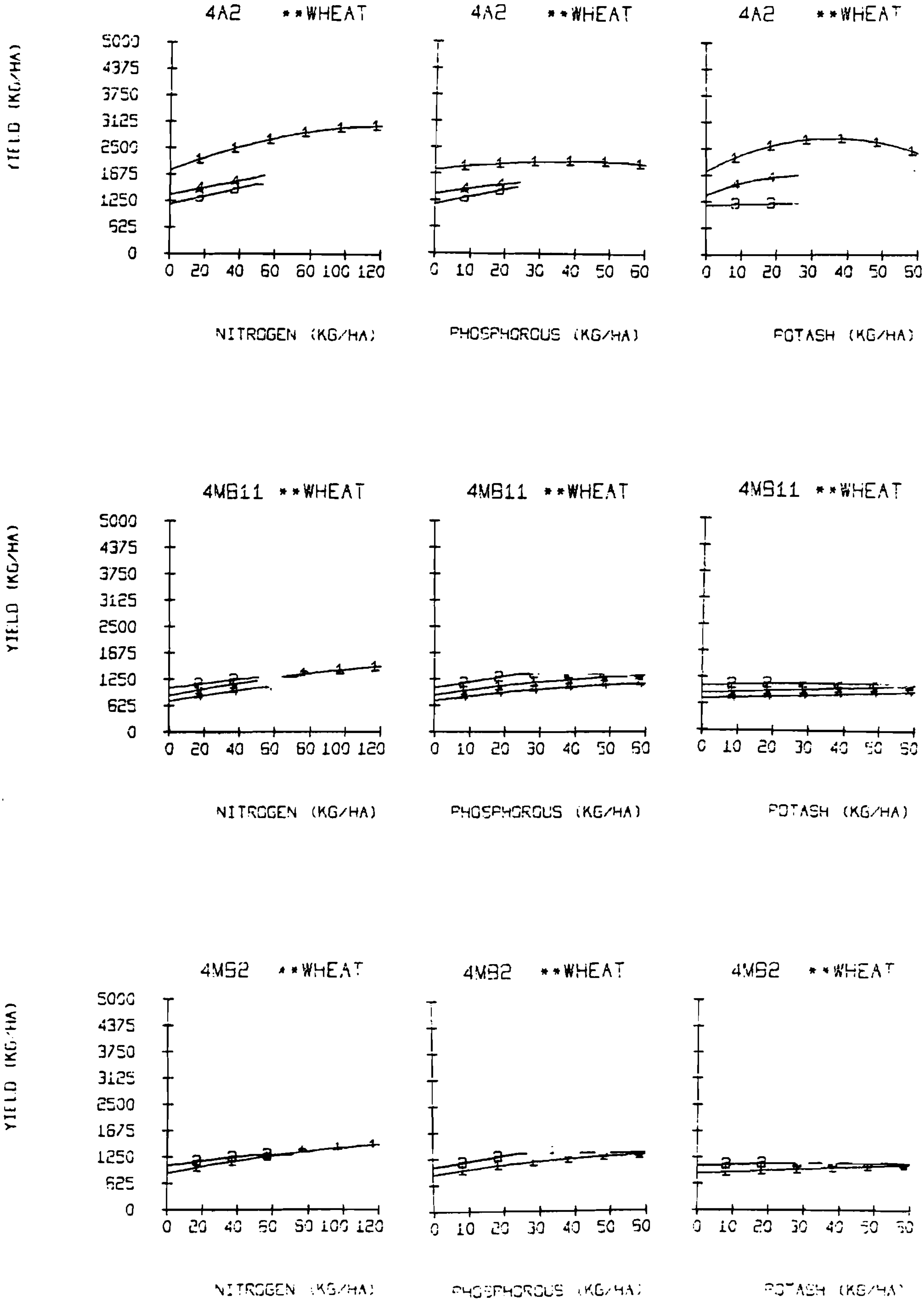

Figure A.4 (contd)

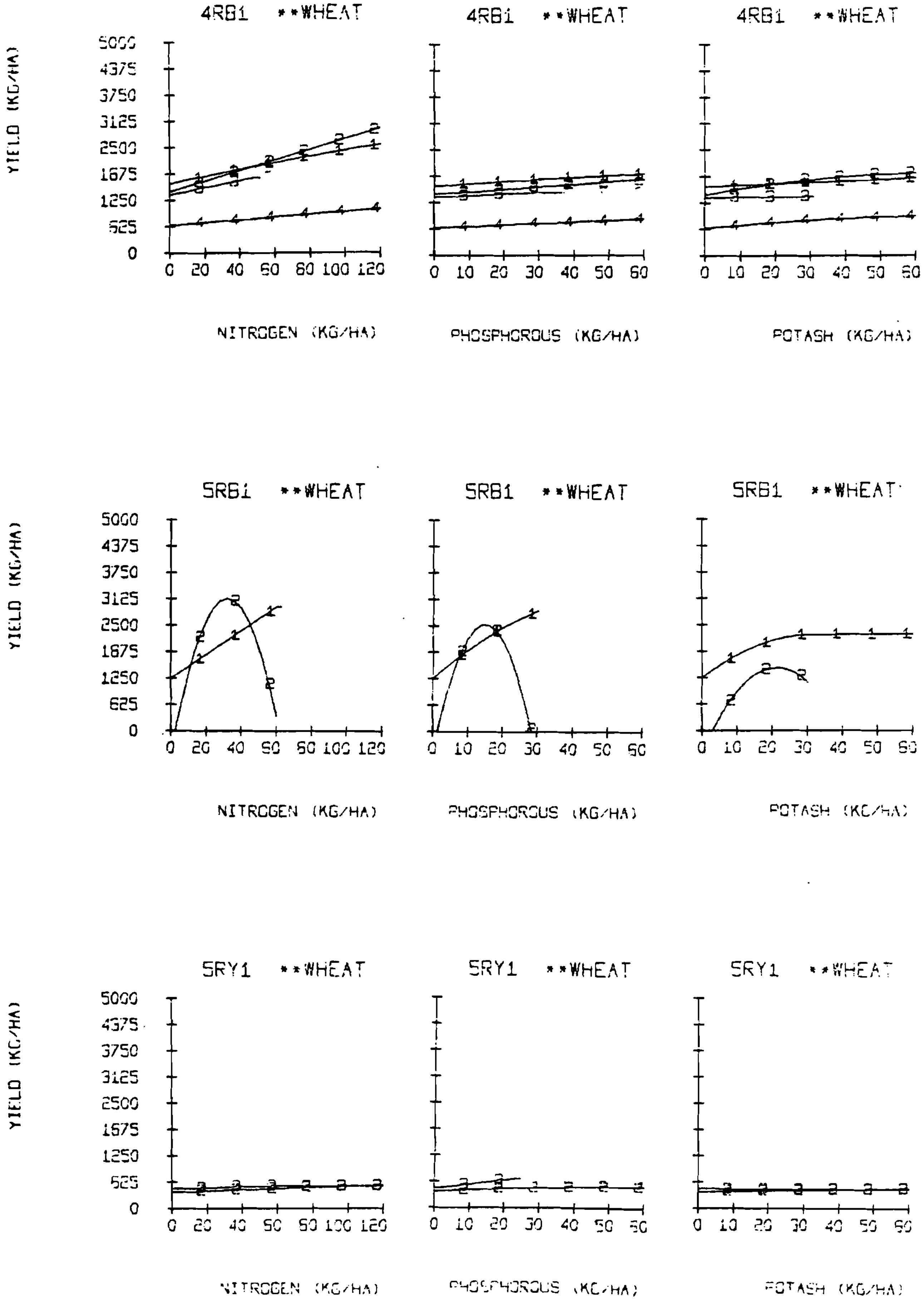

Figure A.4 (contd)

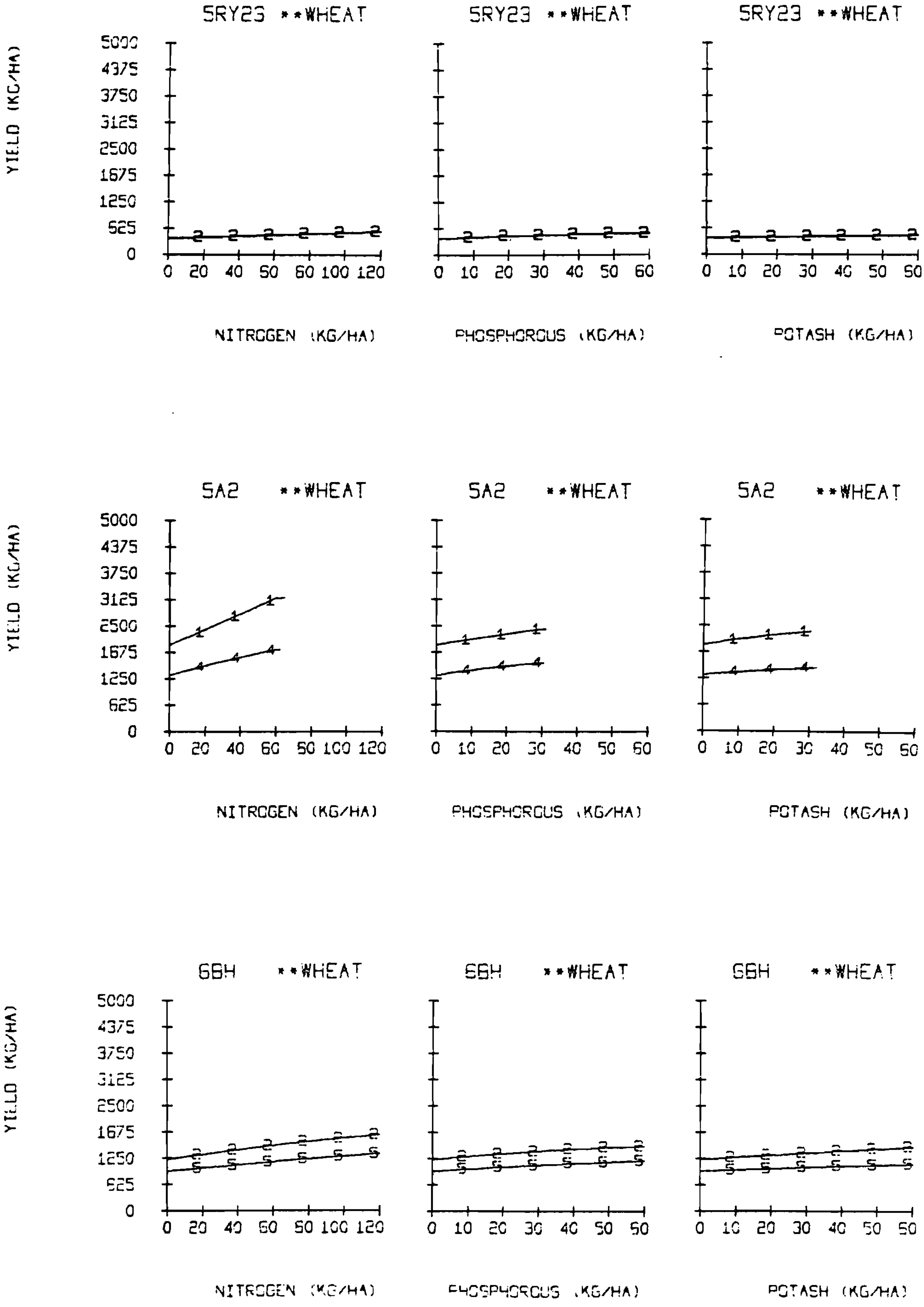

Figure A.4 (contd)

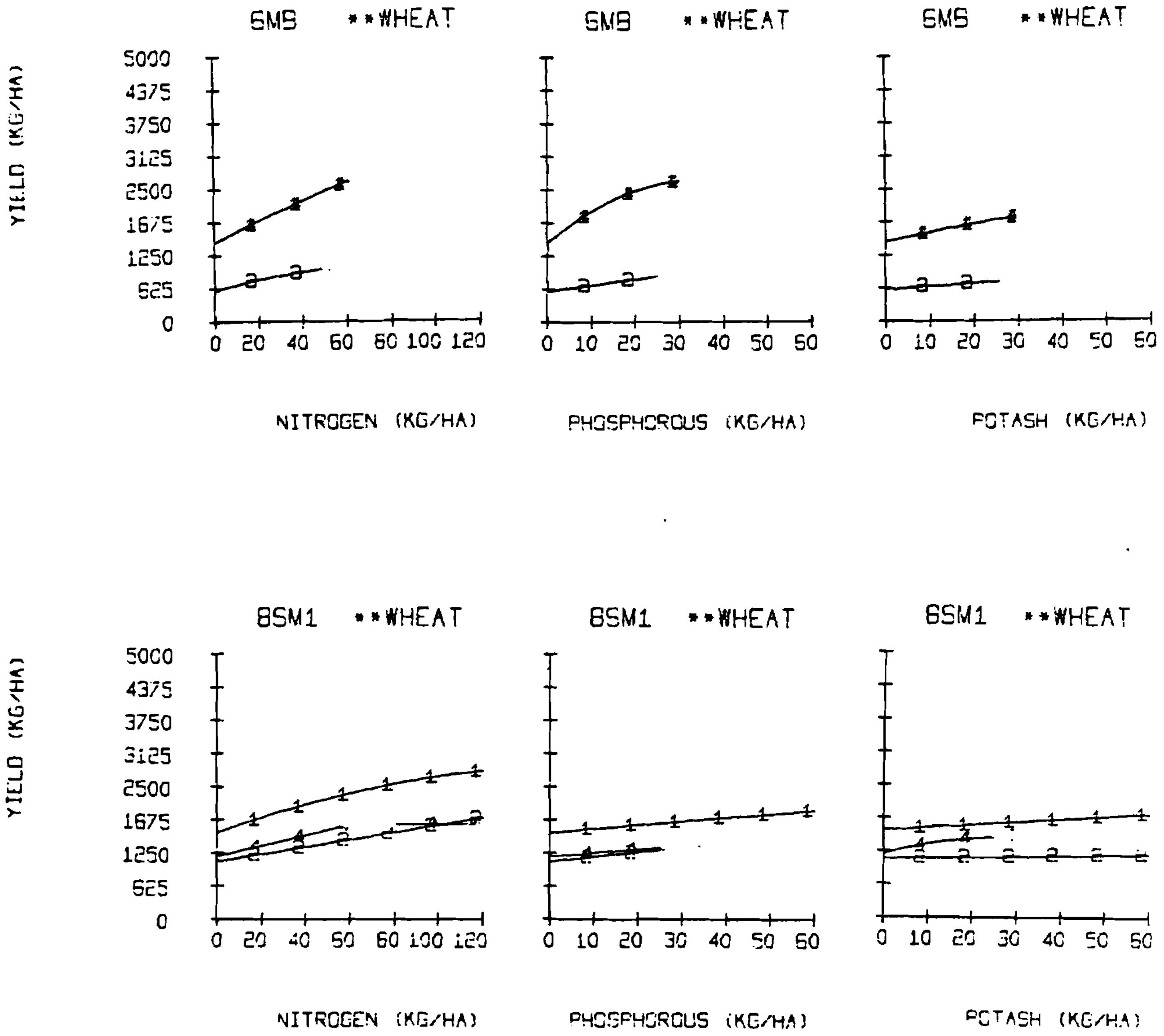

Figure A.5 **Yield Responses of Maize**

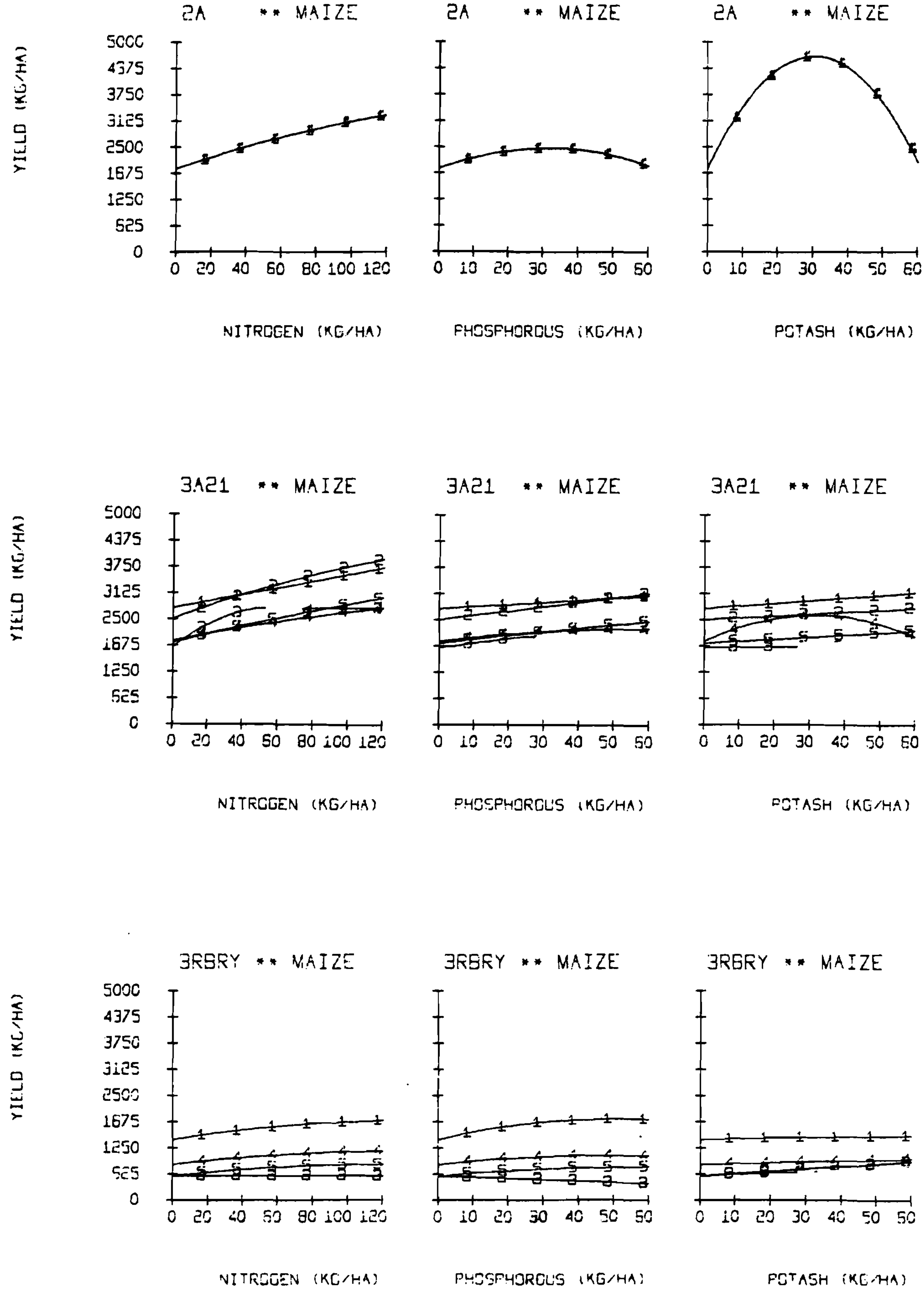

Figure A.5 (contd)

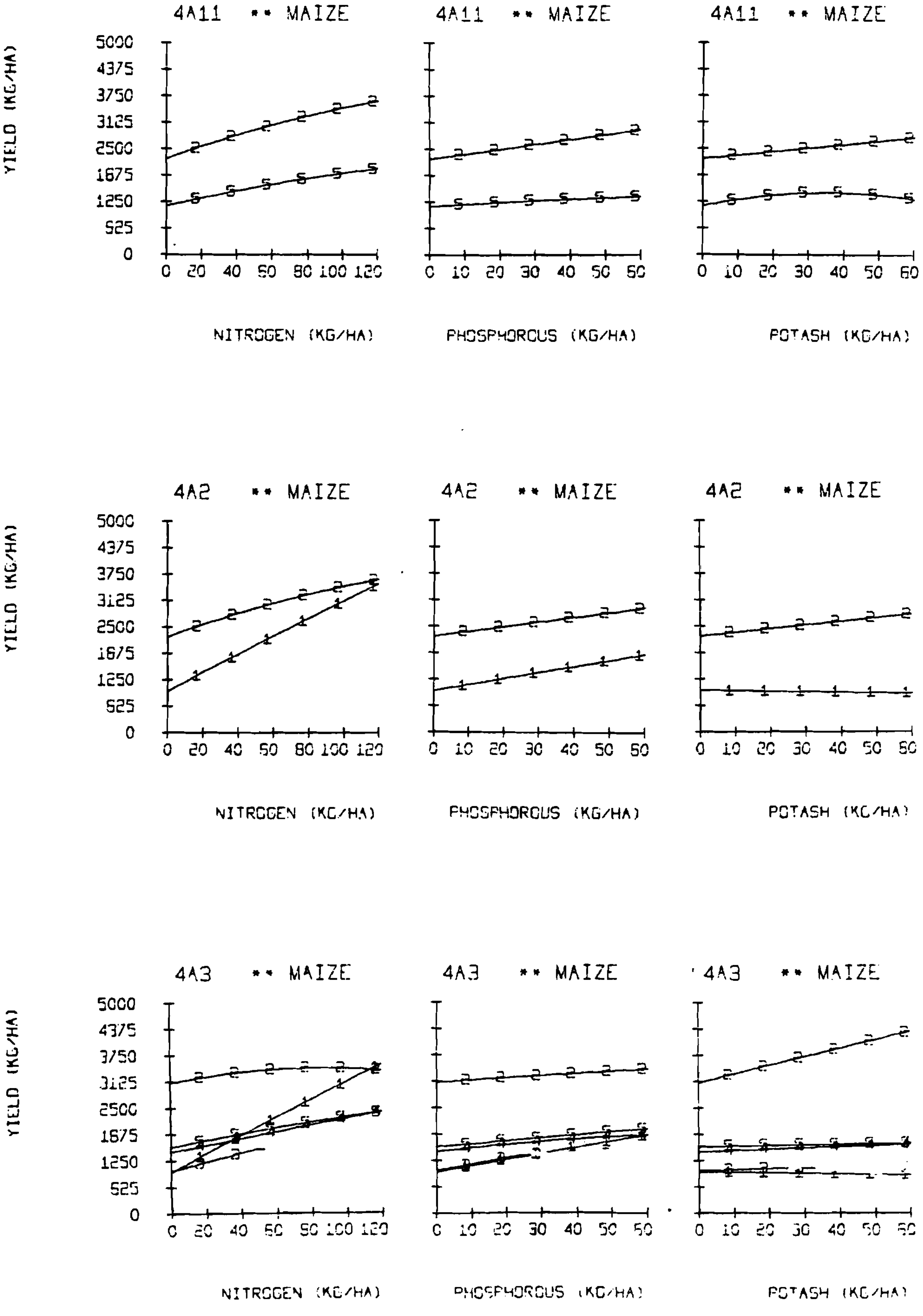

Figure A.5 (contd)

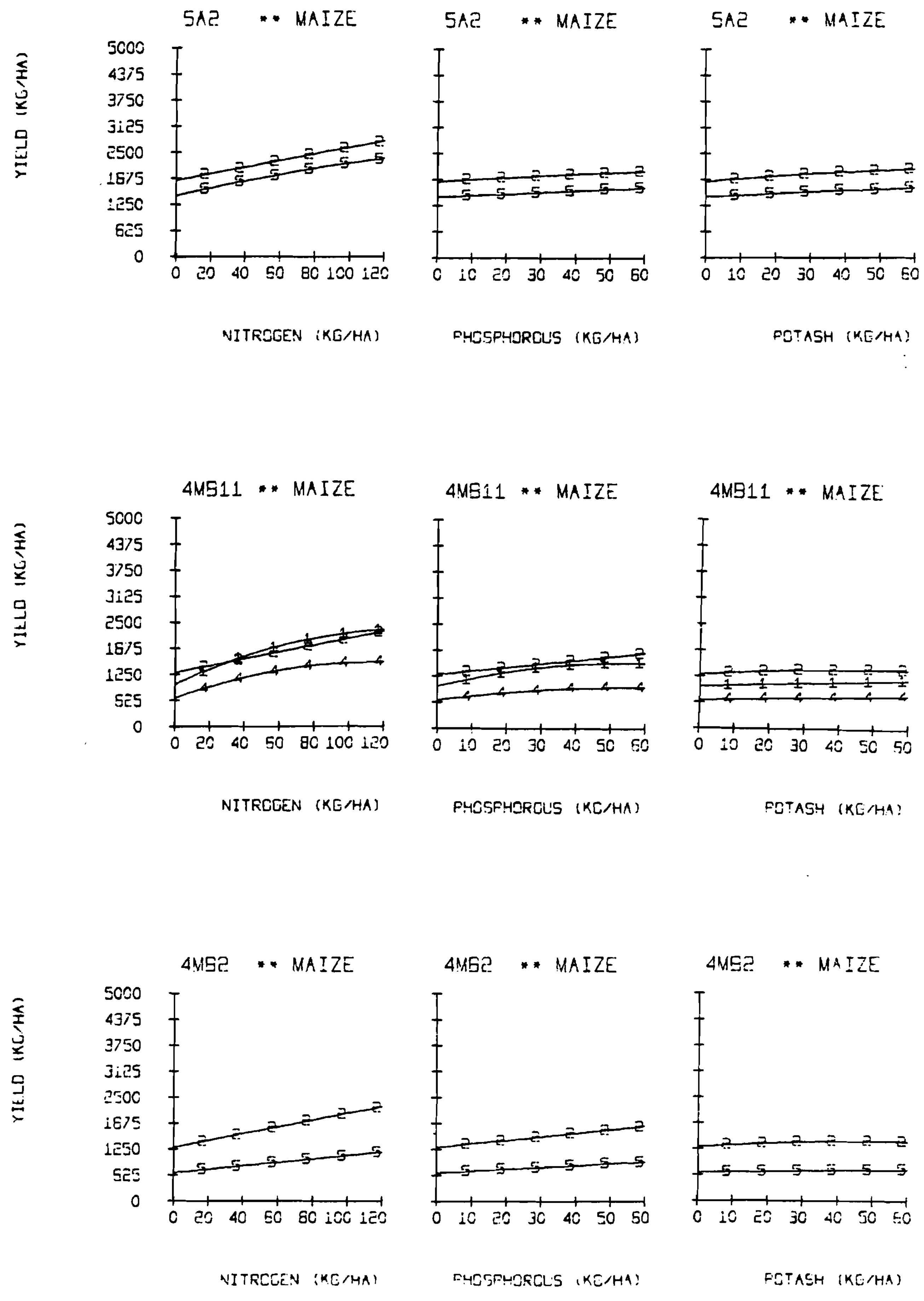

Figure A.5 (contd)

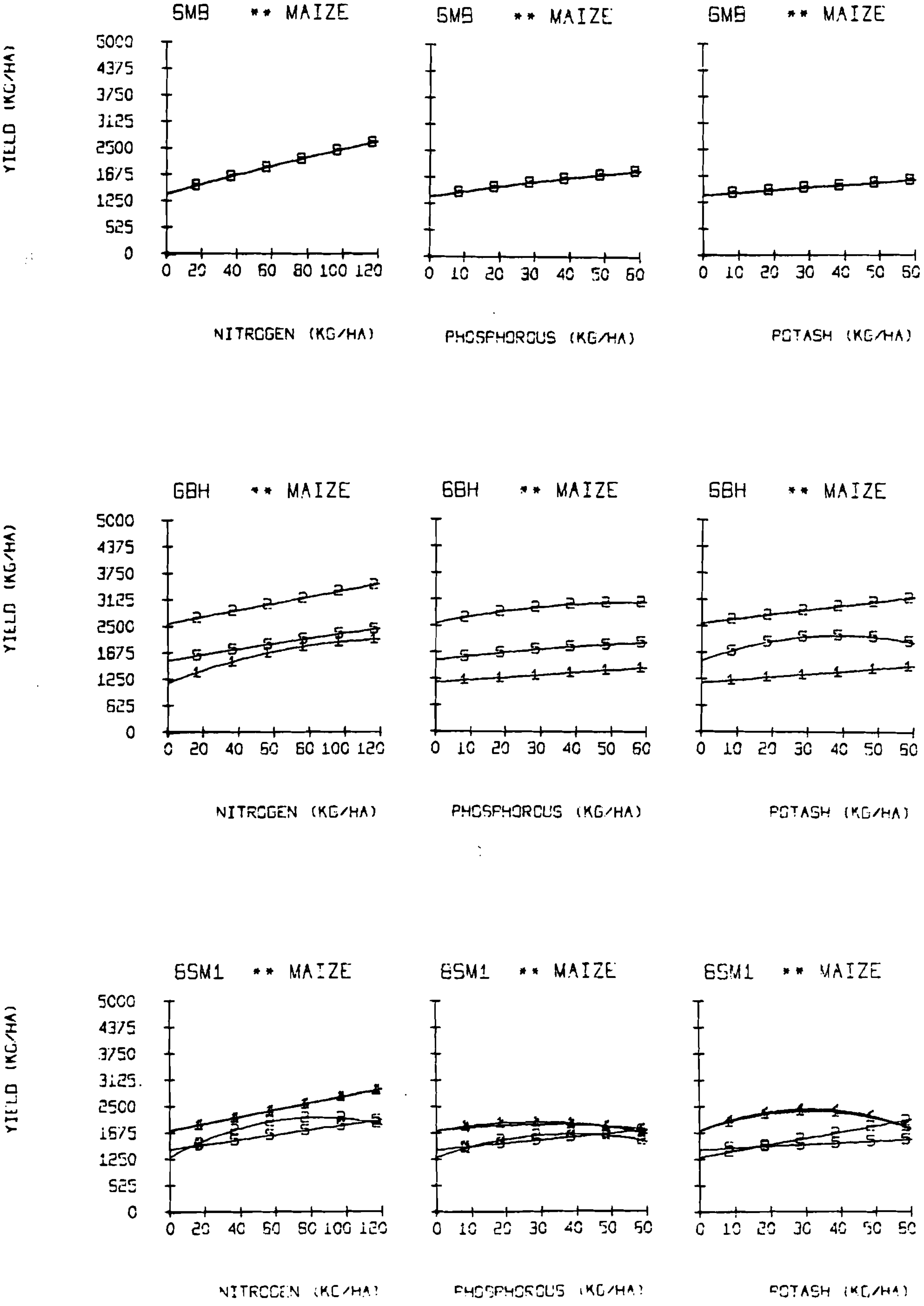

Figure A.6 **Yield Response of Jowar**

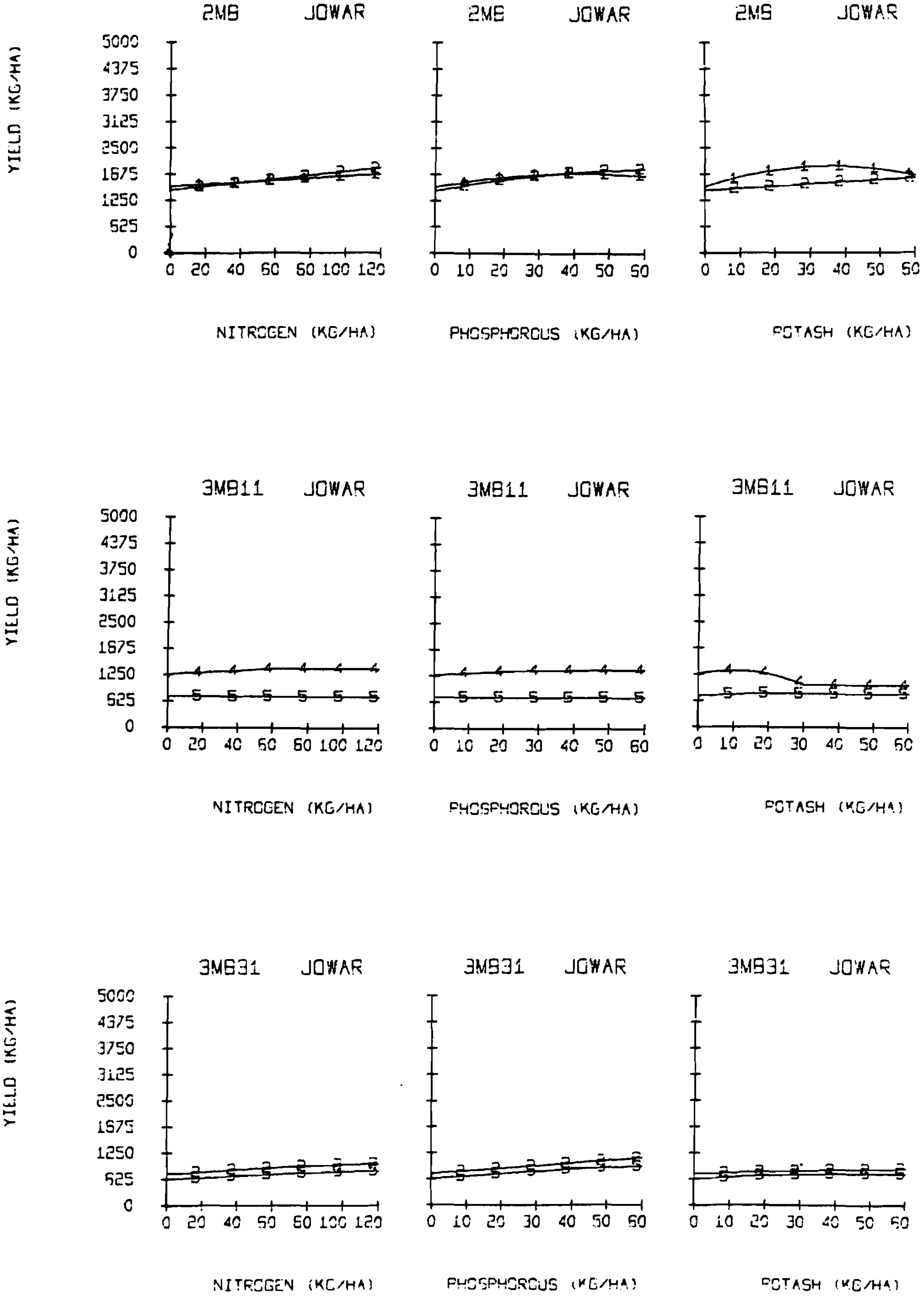

Figure A.6 (contd)

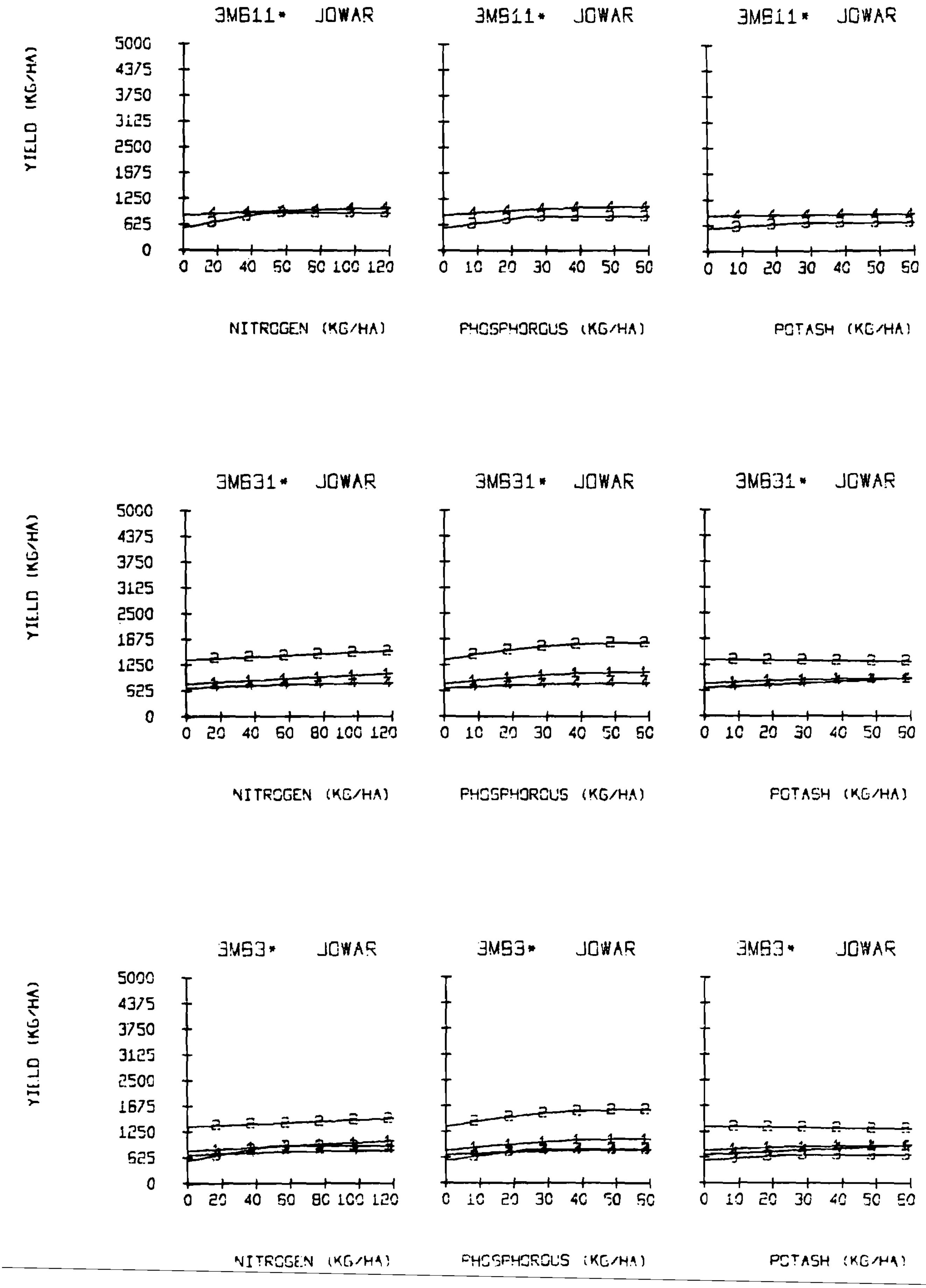

Figure A.6 (contd)

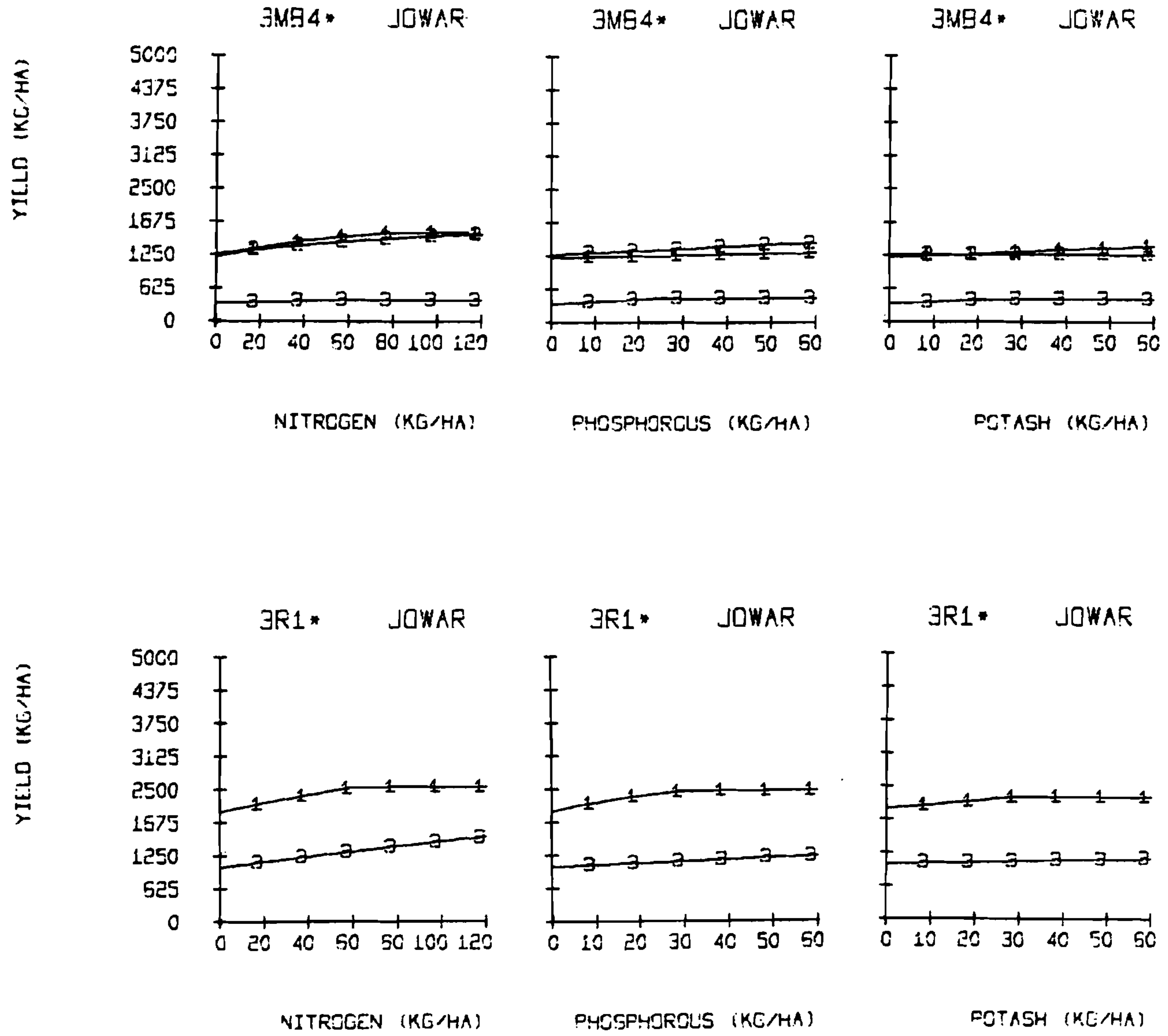

Figure A.6 (contd)

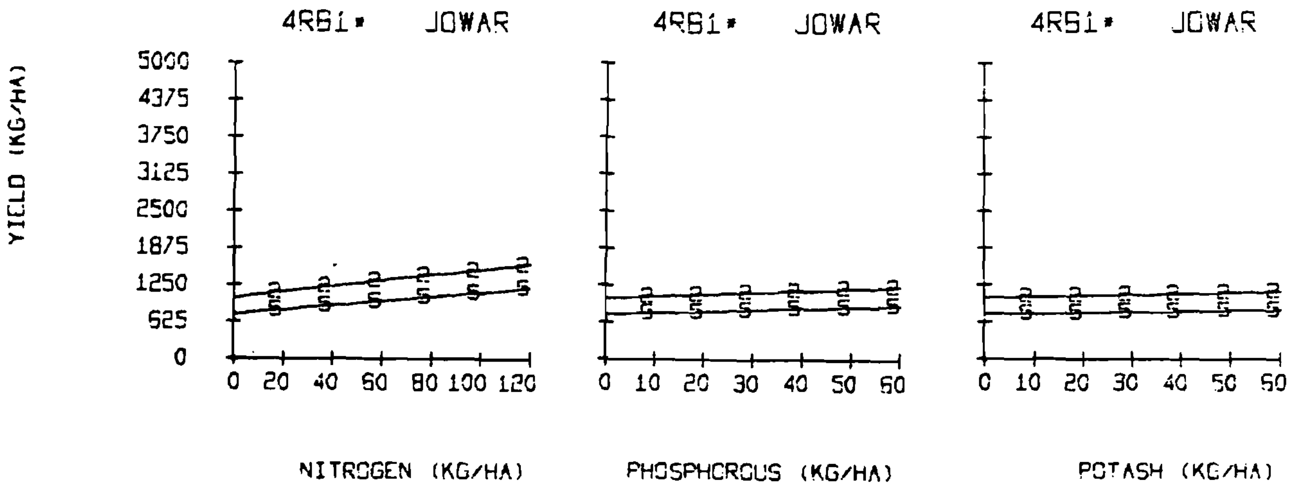

Figure A.7 **Yield Response of Bajra**

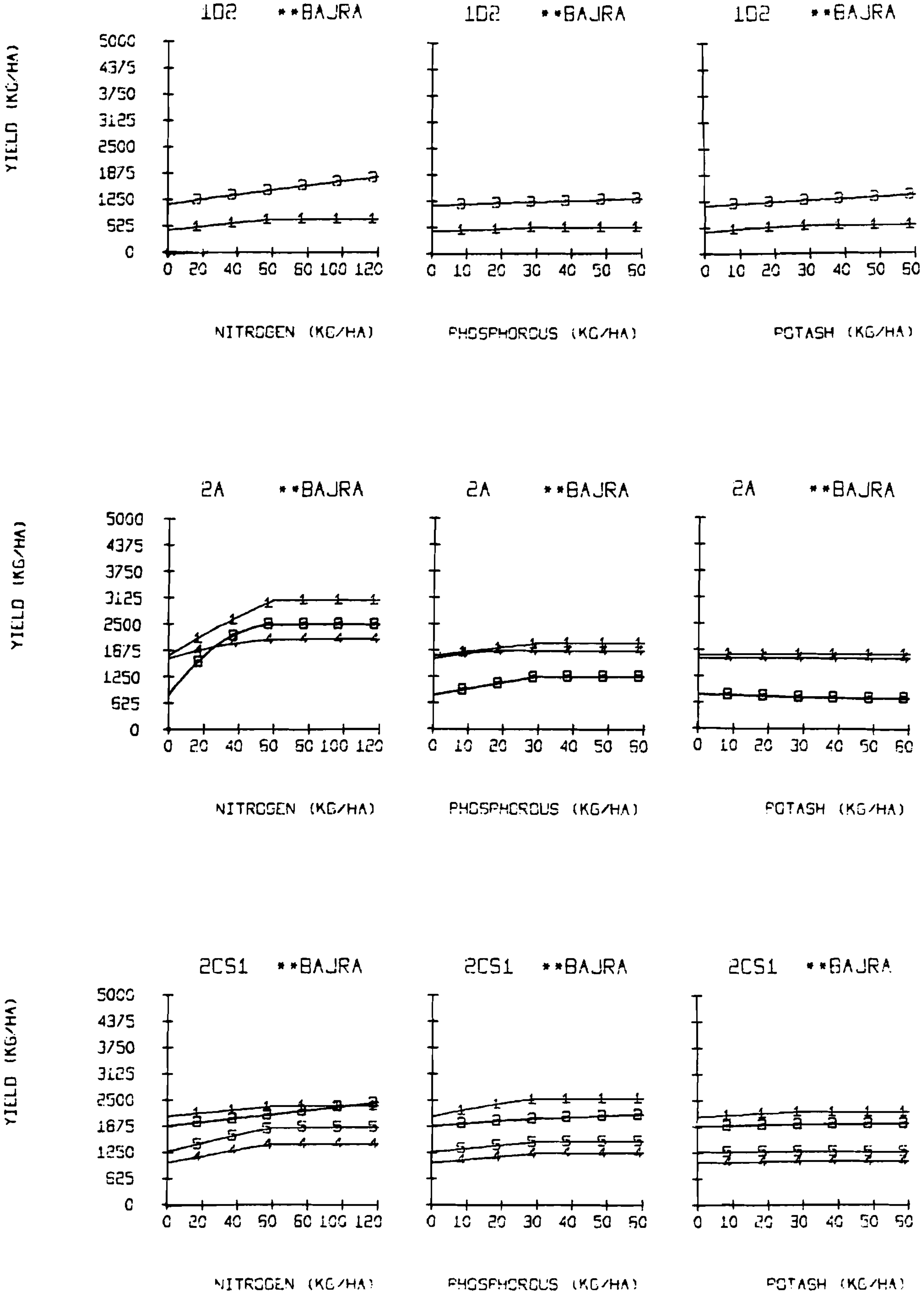

Figure A.7 (contd)

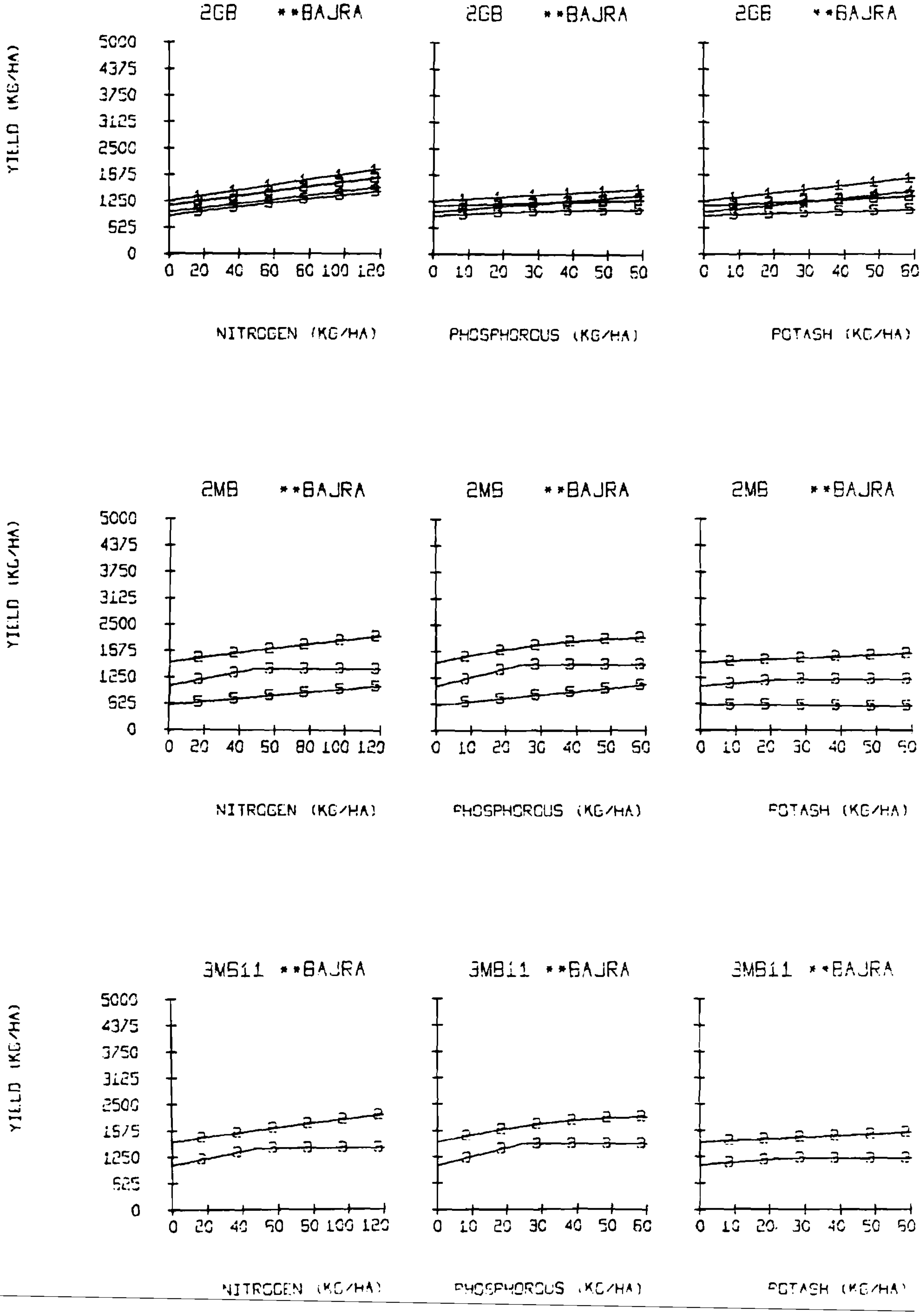

Figure A.7 (contd)

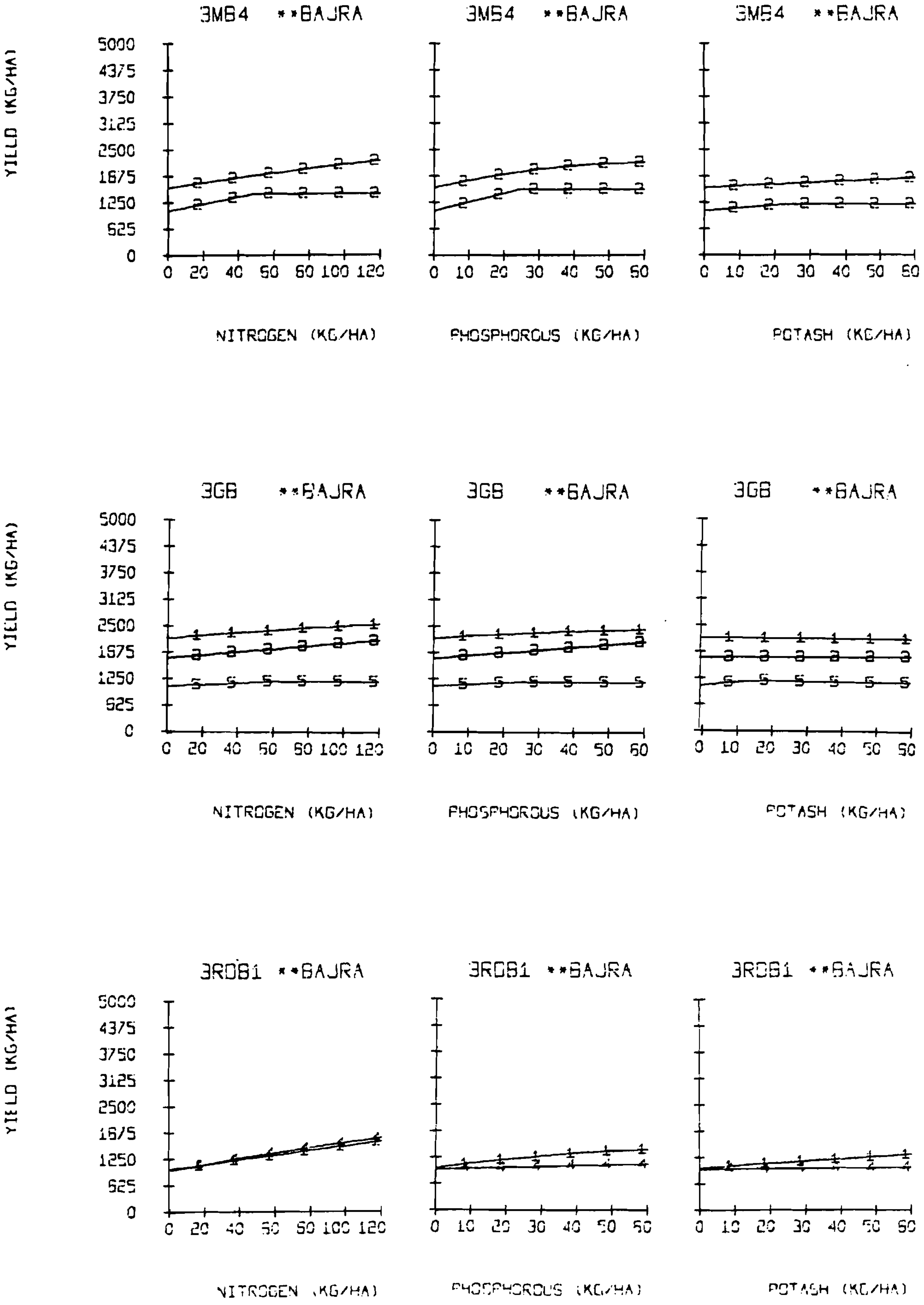

Figure A.7 (contd)

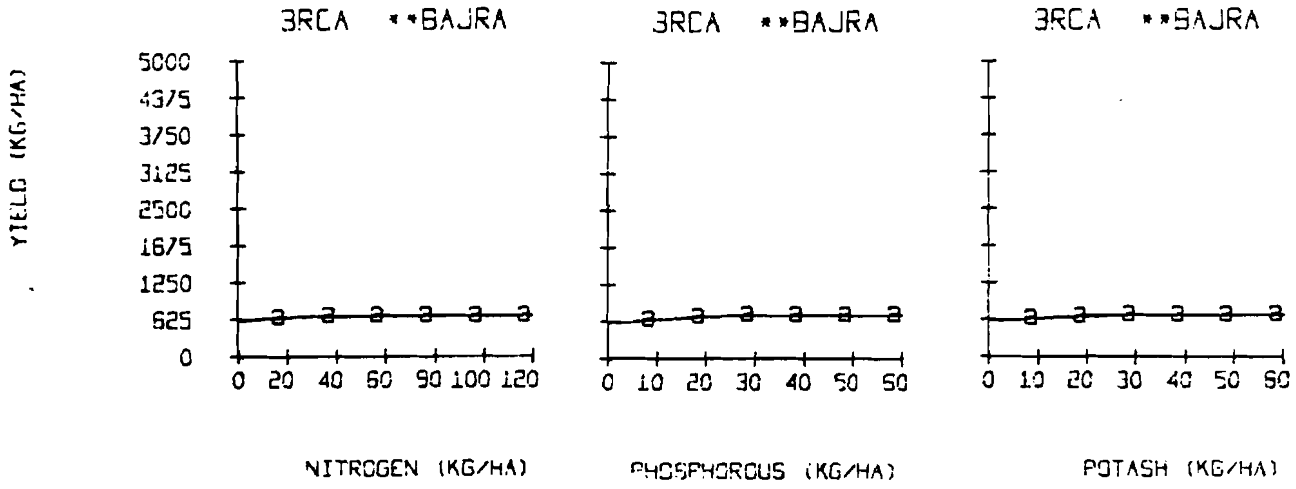

Figure A.8 Yield Response of Ground Nut

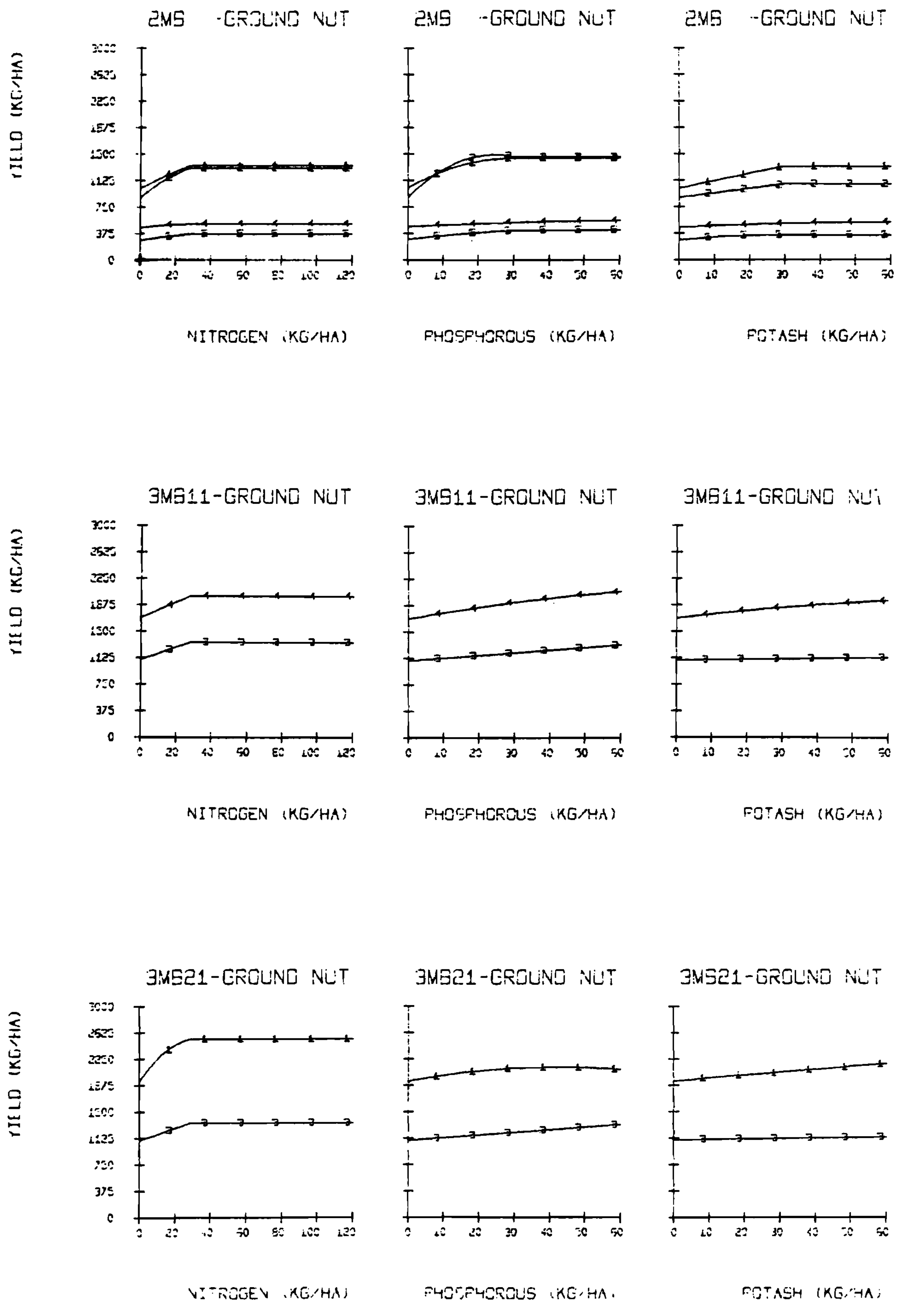

Figure A.8 (contd)

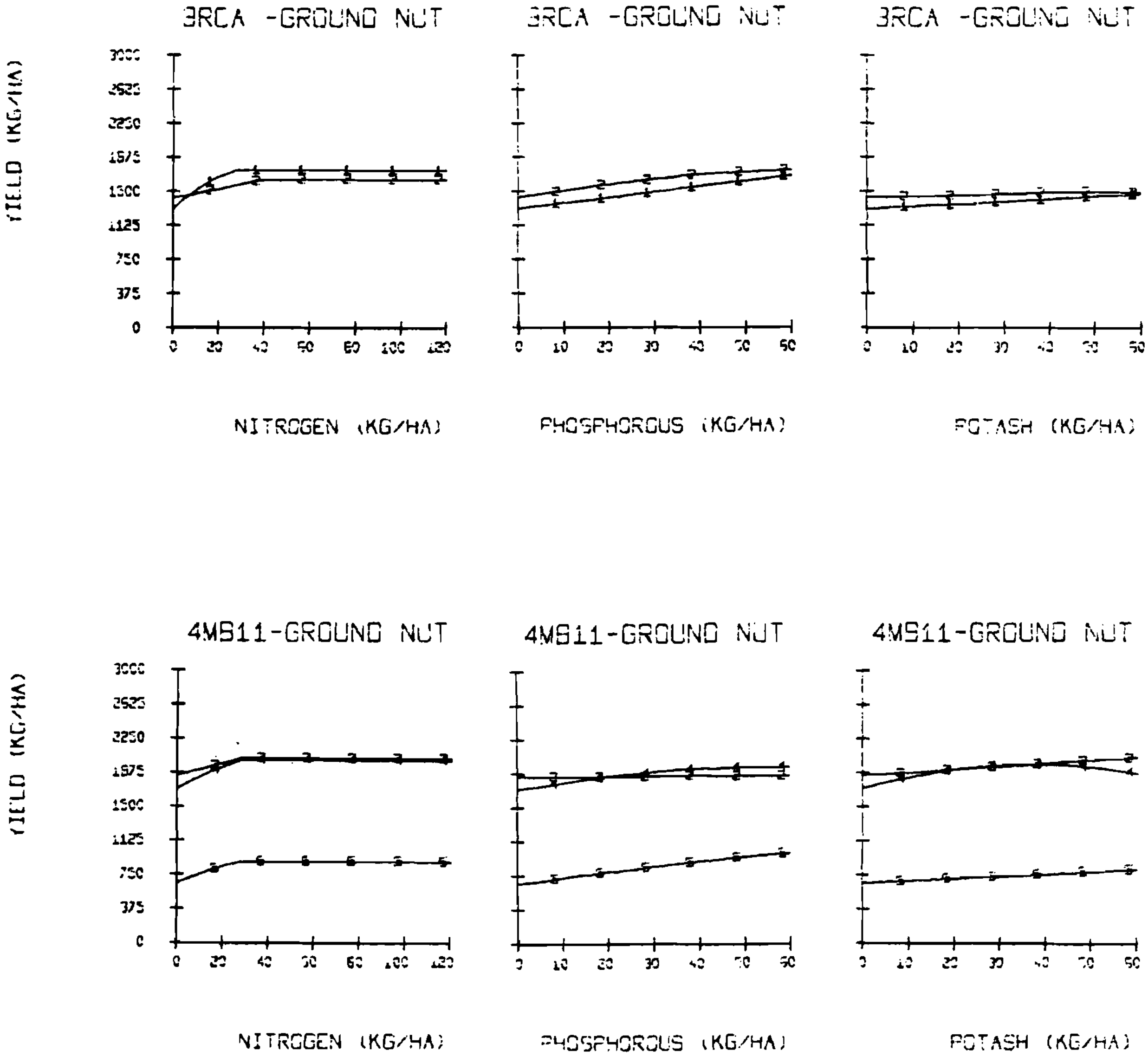

Figure A.9 Yield Response of Cotton

Figure A.10 **Yield Response of Gram**

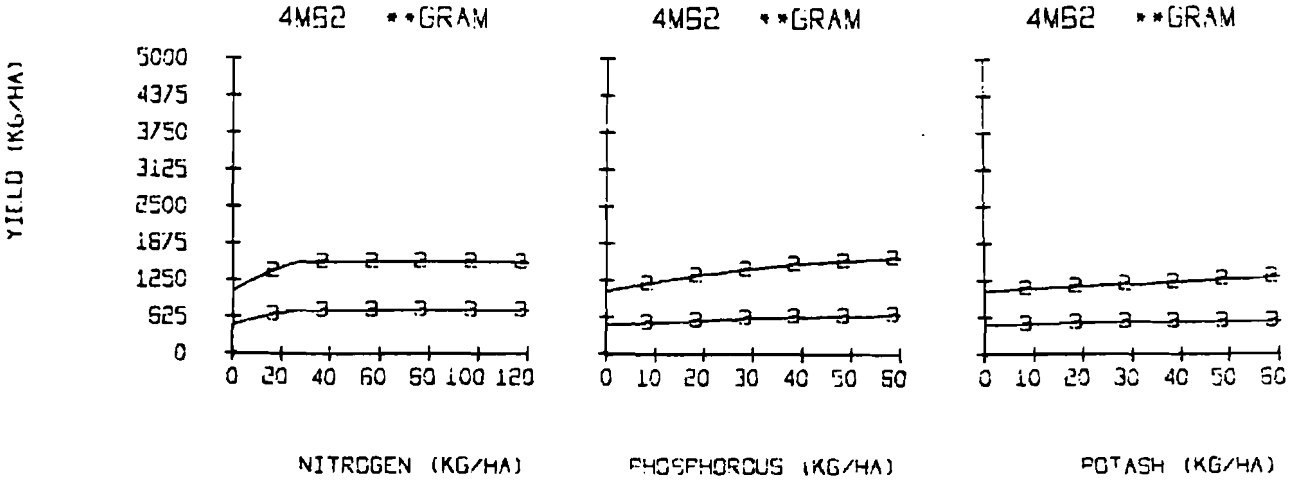

TABLE A.1: WINTER PADDY

ZONE	VARIETY- IRRIG./UNIRR.	ESTIMATED COEFFICIENTS OF THE YIELD RESPONSE FUNCTION y= a0 +a1*N +a2*(N**2) +b1*P +b2*(P**2) +c1*K +c2*(K**2) a0	a1	a2	b1	b2	c1	c2	NUMBER OF REPLICAT.
w. paddy									
3a21	n-u	1742.	13.61	0.000	40.55	-0.555	7.50	0.000	10
3a21	l-i	2150.	21.18	-0.129	20.72	-0.280	8.98	-0.083	390
3a21	l-u	1742.	13.61	0.000	40.55	-0.555	7.50	0.000	10
w. paddy									
3rbl	h-i	3445.	12.94	-0.022	26.15	-0.159	4.41	0.000	940
3rbl	l-i	1483.	5.45	-0.022	9.36	-0.021	3.21	0.000	370
w. paddy									
4all	h-i	1518.	19.11	-0.064	12.91	-0.073	4.64	0.000	630
4all	l-i	1547.	12.34	-0.063	12.98	-0.210	0.17	-0.257	440
w. paddy									
4a2	h-i	1915.	9.76	-0.004	9.66	0.000	2.69	0.000	1390
4a2	dry	2017.	14.35	0.000	8.43	0.000	4.58	0.000	204
4a2	l-i	1547.	12.34	-0.053	12.98	-0.210	16.78	-0.257	440
4a2	l-u	2758.	11.24	-0.001	9.94	-0.153	4.16	0.000	130
w. paddy									
4a3	n-i	2554.	13.34	0.000	29.11	-0.222	33.78	0.000	10
4a3	l-i	1925.	10.88	-0.031	18.98	-0.317	3.62	0.000	130
4a3	l-u	1394.	21.14	-0.124	15.51	-0.002	0.16	0.000	50
w. paddy									
4moll	h-i	3097.	19.59	-0.097	27.70	-0.420	88.40	-1.278	550
4moll	l-i	2423.	10.72	0.000	22.42	0.000	1.55	0.000	280
w. paddy									
4rl	h-i	4427.	12.15	0.000	24.29	-0.069	6.34	0.000	410
4rl	h-u	2629.	5.95	-0.037	8.38	0.000	2.57	0.000	30
4rl	dry	2108.	3.85	0.000	15.36	0.000	4.61	0.000	18
4rl	l-i	4425.	11.34	0.000	28.06	-0.188	7.64	0.000	60
w. paddy									
4rcal	h-i	2194.	10.85	-0.024	38.62	-0.329	7.25	0.000	270
4rcal	l-i	1483.	5.45	-0.022	9.36	-0.021	3.21	0.000	370
w. paddy									
5all	h-i	3466.	13.55	-0.050	10.46	-0.060	4.57	0.000	180
5all	l-i	2617.	13.44	-0.063	6.65	-0.059	1.71	0.000	150
5all	l-u	2417.	14.06	-0.069	8.57	-0.073	2.99	-0.016	90
5all	n-u	3952.	7.25	-0.008	9.20	0.000	19.54	-0.245	190
w. paddy									
5a2	l-i	1788.	10.05	0.000	4.76	-0.014	6.40	-0.060	230
5a2	l-u	1059.	6.86	0.000	1.86	0.000	3.37	-0.047	10
5a2	h-i	2311.	34.22	-0.161	25.84	-0.376	7.60	0.000	10
5a2	n-u	3574.	31.36	-0.117	11.56	-0.090	8.32	-0.032	40
w. paddy									
5al2	l-i	2617.	13.44	-0.063	6.65	-0.059	1.71	0.000	150
5al2	l-u	2417.	14.06	-0.069	8.57	-0.073	2.99	-0.016	90
5al2	h-i	3466.	13.55	-0.050	10.46	-0.060	4.57	0.000	180
5al2	n-u	3952.	7.25	-0.008	9.20	0.000	19.54	-0.246	190
w. paddy									
5ry21	h-i	3084.	8.35	-0.003	30.50	-0.228	5.01	0.000	1330
5ry21	n-u	2966.	10.49	0.000	18.56	0.000	5.97	0.000	320
w. paddy									
5ryl	h-i	2270.	9.88	-0.005	16.86	-0.093	9.15	0.000	310
5ryl	h-u	2680.	6.23	-0.039	33.62	-0.289	5.51	0.000	80
5ryl	l-i	4425.	11.34	0.000	28.06	-0.188	7.64	0.000	60
w. paddy									
5ry31	h-i	3084.	8.35	-0.003	30.50	-0.228	5.01	0.000	1330
5ry31	h-u	2966.	10.49	0.000	18.56	0.000	5.97	0.000	320
w. paddy									
6al	h-i	2311.	34.22	-0.161	26.84	-0.376	7.60	0.000	10
6al	h-u	3574.	31.36	-0.117	11.56	-0.090	8.32	-0.032	40
w. paddy									
7lcal	h-i	3406.	18.34	-0.094	27.75	-0.454	17.23	0.000	200
7lcal	h-u	3759.	13.53	-0.051	8.51	-0.073	19.14	-0.314	640
7lcal	l-i	3135.	15.78	-0.094	9.40	-0.089	15.39	-0.054	30
7lcal	l-u	1524.	3.56	0.000	6.35	0.000	5.80	0.000	110
w. paddy									
7d-ry	l-u	3503.	11.00	-0.015	21.52	-0.140	5.94	0.000	350
7d-ry	h-i	2956.	12.04	-0.035	23.13	-0.173	6.38	0.000	220
7d-ry	h-u	4021.	16.16	-0.049	20.82	-0.111	11.18	0.000	280
7d-ry	l-i	2956.	12.04	-0.035	23.13	-0.173	6.38	0.000	220
w. paddy									
dsml	h-i	2639.	16.03	-0.044	9.30	0.000	0.47	0.000	100
dsml	h-u	2427.	13.14	0.000	16.47	-0.160	5.01	0.000	20
dsml	l-i	1814.	6.98	0.000	18.50	0.000	11.74	0.000	160

TABLE A.2: AUTUMN PADDY

ZONE	VARIETY- IRRIG./UNIRR.	ESTIMATED COEFFICIENTS OF THE YIELD RESPONSE FUNCTION y= a0 +a1*N +a2*(N**2) +b1*P +b2*(P**2) +c1*K +c2*(K**2) a0	a1	a2	b1	b2	c1	c2	NUMBER OF REPLICAT.
autumn paddy									
oalry*	l-i	1633.	6.47	0.000	20.48	-0.255	14.18	0.000	190
oalry*	l-u	1069.	3.87	0.000	20.58	-0.351	18.27	-0.439	90
autumn paddy									
5ryl*	n-i	7226.	63.25	-0.671	112.64	-2.403	49.54	0.000	10
5ryl*	h-u	3610.	26.69	-0.135	47.41	-0.666	33.04	-0.610	230
5ryl*	l-u	1696.	4.99	-0.015	9.31	-0.075	12.06	-0.169	250
autumn paddy									
6-7db*	h-i	1907.	4.18	0.000	8.60	0.000	18.51	-0.283	230
6-7db*	n-u	1377.	7.54	0.000	4.38	0.000	10.07	0.000	140
6-7db*	l-u	898.	3.83	0.000	6.99	-0.018	6.36	0.000	390
autumn paddy									
71cal4	h-u	3457.	11.13	-0.030	12.92	-0.085	4.08	0.000	2130
71cal4	n-i	4276.	13.33	-0.049	13.53	-0.023	0.32	0.000	160

TABLE A.3: WHEAT

ZONE	VARIETY- IRRIG./UNIRR.	ESTIMATED COEFFICIENTS OF THE YIELD RESPONSE FUNCTION y= a0 +a1*N +a2*(N**2) +b1*P +b2*(P**2) +c1*K +c2*(K**2) a0	a1	a2	b1	b2	c1	c2	NUMBER OF REPLICAT.
**wheat									
2gb	h-i	1563.	8.85	-0.009	9.75	-0.073	4.75	0.000	980
2gb	l-i	1486.	3.71	-0.013	21.74	-0.251	8.79	0.000	90
**wheat									
2mb	h-i	1655.	5.41	-0.006	17.96	-3.127	4.18	0.000	1340
2mb	l-i	1044.	19.44	-0.341	19.16	-0.166	7.04	0.000	210
**wheat									
2csl	h-i	2326.	23.03	-0.085	22.14	-0.198	29.80	-0.425	1800
2csl	dry	814.	16.20	-0.105	12.26	0.000	2.70	0.000	228
**wheat									
3a11	h-i	2528.	22.80	-0.040	20.93	-0.103	5.23	0.000	1280
3a11	h-u	1440.	5.66	-0.071	22.44	-0.262	14.76	0.000	30
3a11	dry	814.	16.20	-0.105	12.26	0.000	2.70	0.000	228
**wheat									
3a21	h-i	2326.	23.03	-0.085	22.14	-0.198	29.80	-0.425	1800
3a21	h-u	1440.	5.66	-0.071	22.44	-0.262	14.76	0.000	30
3a21	dry	814.	16.20	-0.105	12.26	0.000	2.70	0.000	228
3a21	l-i	1560.	17.06	-0.019	11.46	0.000	14.69	-0.263	220
3a21	l-u	1440.	5.66	-0.071	22.44	-0.262	14.76	0.000	30
**wheat									
3gb	h-i	2669.	5.43	0.000	19.27	-0.157	1.26	0.000	1070
3gb	l-i	1842.	3.19	0.000	4.15	0.000	10.23	-0.161	40
**wheat									
3rdol	h-i	1009.	8.73	-0.011	2.49	-0.033	3.52	0.000	420
3rdol	l-i	1009.	8.73	-0.011	2.49	-0.023	3.52	0.000	420
**wheat									
3rbry	h-i	1218.	28.03	-0.228	15.92	0.000	18.10	-0.408	230
3rbry	l-i	1093.	6.46	-0.007	20.39	-0.347	8.19	-0.091	220
**wheat									
3mb11	h-u	556.	9.39	0.000	21.66	0.000	15.11	0.000	10
3mb11	l-i	1389.	12.38	-0.045	30.13	-0.531	17.92	-0.263	300
3mb11	h-i	1455.	22.29	-0.136	39.41	-0.546	92.26	-1.331	310
**wheat									
3mb3	h-i	1389.	9.50	-0.024	16.89	-0.130	3.48	0.000	1260
3mb3	h-u	556.	9.39	0.000	21.66	0.000	15.11	0.000	10
**wheat									
3mb4	h-i	1389.	9.50	-0.024	16.89	-0.130	3.48	0.000	1260
3mb4	h-u	556.	9.39	0.000	21.66	0.000	15.11	0.000	10
**wheat									
4a11	h-i	2479.	17.65	-0.032	22.52	-0.129	3.89	0.000	550
4a11	h-u	1402.	21.98	-0.037	7.30	0.000	3.22	0.000	50
**wheat									
4a2	h-i	1969.	16.85	-0.067	11.59	-0.153	43.77	-0.611	1660
4a2	dry	1168.	9.78	0.000	17.65	0.000	2.05	0.000	174
4a2	l-i	1397.	8.40	0.000	16.06	-0.169	34.88	-0.638	140
**wheat									
4mb11	h-i	870.	8.35	-0.023	13.51	-0.096	3.49	0.000	130
4mb11	h-u	1047.	5.82	-0.013	13.61	0.000	2.96	0.000	78
4mb11	l-i	737.	7.27	-0.018	11.82	-0.083	3.31	0.000	130
**wheat									
4mb2	h-i	870.	8.36	-0.023	13.51	-0.096	3.49	0.000	130
4mb2	dry	1047.	5.82	-0.013	13.61	0.000	2.96	0.000	78
4mb2	h-u	1047.	5.82	-0.013	13.61	0.000	2.96	0.000	78

TABLE A.3: WHEAT (Contd)

ZONE	VARIETY- IRRIG./UNIRR.	ESTIMATED COEFFICIENTS OF THE YIELD RESPONSE FUNCTION y= a0 +a1*N +a2*(N**2) +b1*P +b2*(P**2) +c1*K +c2*(K**2) a0	a1	a2	b1	b2	c1	c2	NUMBER OF REPLICAT.
**wheat									
4rbl	h-i	1641.	8.84	-0.009	5.82	-0.020	3.29	0.000	1720
4rbl	h-u	1448.	12.47	0.000	5.73	0.000	14.93	-0.107	10
4rbl	dry	1375.	8.60	-0.034	4.18	0.000	0.90	0.000	108
4rbl	l-i	652.	3.20	0.000	3.39	0.000	7.94	-0.052	60
**wheat									
5rbl	h-i	1249.	28.24	0.000	74.08	-0.677	64.30	-1.337	130
5rbl	h-u	-533.	228.60	-3.559	416.90	-14.130	190.50	-4.479	20
**wheat									
5ryl	h-u	388.	1.41	0.000	3.73	-0.032	1.38	0.000	190
5ryl	dry	457.	1.46	0.000	9.79	0.000	-0.20	0.002	54
**wheat									
5ry21	h-u	388.	1.41	0.000	3.73	-0.032	1.38	0.000	190
5ry22	h-u	388.	1.41	0.000	3.73	-0.032	1.38	0.000	190
5ry23	h-u	388.	1.41	0.000	3.73	-0.032	1.38	0.000	190
**wheat									
5a2	l-i	1329.	11.74	-0.029	13.71	-0.131	7.79	-0.264	90
5a2	h-i	2049.	18.28	0.000	14.58	-0.062	14.56	-0.126	510
**wheat									
6bh	h-u	1223.	6.20	-0.011	7.88	-0.041	4.92	0.000	550
6bn	l-u	943.	3.95	-0.003	5.36	-0.019	2.79	0.000	330
**wheat									
6mb	h-i	1494.	21.52	-0.039	70.40	-1.034	18.03	-0.072	10
6mb	dry	588.	11.96	-0.077	11.35	0.000	5.64	0.000	192
6mb	h-u	588.	11.96	-0.077	11.35	0.000	5.64	0.000	192
6mb	l-i	1494.	21.52	-0.039	70.40	-1.034	18.03	-0.072	10
**wheat									
8sml	h-i	1632.	15.12	-0.045	7.85	-0.013	5.36	0.000	250
8sml	h-u	1088.	6.88	0.000	9.87	-0.038	1.54	0.000	130
8sml	l-i	1187.	9.95	0.000	6.97	0.000	21.95	-0.373	130

TABLE A.4: MAIZE

		ESTIMATED COEFFICIENTS OF THE YIELD RESPONSE FUNCTION y= a0 +a1*N +a2*(N**2) +b1*P +b2'(P**2) +c1*K +c2*(K**2)							NUMBER OF
ZONE	VARIETY- IRRIG./UNIRR.	a0	a1	a2	b1	b2	c1	c2	REPLICAT.
** maize varieties **									
2a	n-i	1977.	14.47	-0.032	31.14	-0.502	175.50	-2.880	210
2a	l-i	1977.	14.47	-0.032	31.14	-0.502	175.50	-2.880	210
** maize varieties **									
3a21	h-i	2768.	8.17	0.000	5.25	0.000	6.44	0.000	180
3a21	h-u	2506.	16.20	-0.035	10.60	0.000	4.55	0.000	100
3a21	dry	1834.	32.31	-0.266	11.35	0.000	1.38	0.000	126
3a21	l-i	1985.	9.01	-0.020	11.25	-0.100	40.11	-0.637	1560
3a21	l-u	1942.	10.93	-0.015	10.34	-0.024	5.07	0.000	70
** maize varieties **									
3rbry	h-i	1453.	6.45	-0.023	19.48	-0.196	2.17	-0.013	20
3rbry	h-u	581.	0.00	0.000	-3.19	0.000	5.66	0.000	20
3rbry	dry	581.	0.00	0.000	-3.19	0.000	5.66	0.000	20
3rbry	l-i	854.	4.71	-0.017	8.95	-0.095	2.21	0.000	120
3rbry	l-u	578.	4.62	-0.020	7.49	-0.068	4.42	-0.038	10
** maize varieties **									
4a11	h-u	2267.	15.11	-0.031	11.32	0.000	8.46	0.000	640
4a11	l-u	1146.	9.85	-0.020	5.16	-0.023	18.45	-0.262	870
** maize varieties **									
4a2	n-u	2267.	15.11	-0.031	11.32	0.000	8.46	0.000	640
4a2	h-i	977.	22.29	-0.009	14.47	0.000	-1.34	0.000	20
** maize varieties **									
4a3	h-i	977.	22.29	-0.009	14.47	0.000	-1.34	0.000	20
4a3	h-u	3098.	8.17	-0.049	5.06	0.000	20.08	0.000	10
4a3	dry	1008.	10.70	0.000	15.07	0.000	2.29	0.000	156
4a3	l-i	1458.	7.97	0.000	9.19	-0.044	2.92	0.000	170
4a3	l-u	1570.	8.46	-0.013	7.05	0.000	1.49	0.000	220
** maize varieties **									
5a2	l-u	1457.	9.65	-0.017	3.90	0.000	4.60	-0.016	310
5a2	h-u	1829.	7.99	0.000	5.39	-0.019	7.19	-0.037	140
** maize varieties **									
4mb11	h-i	1013.	19.52	-0.072	20.93	-0.197	2.84	0.000	180
4mb11	n-u	1297.	8.22	0.000	8.52	0.000	5.42	-0.054	90
4mb11	l-i	681.	14.93	-0.064	11.05	-0.099	2.15	0.000	180
** maize varieties **									
4mb2	h-u	1297.	8.22	0.000	8.52	0.000	5.42	-0.054	90
4mb2	l-u	679.	4.17	0.000	4.49	0.000	1.65	-0.009	20
** maize varieties **									
6mb	h-u	1411.	11.63	-0.011	13.45	-0.055	6.12	0.000	20
6mb	l-u	1411.	11.63	-0.011	13.45	-0.055	6.12	0.000	20
** maize varieties **									
6bh	h-i	1162.	15.93	-0.061	5.87	0.000	6.68	0.000	20
6bh	h-u	2567.	7.73	0.000	16.73	-0.145	10.36	0.000	30
6bh	l-u	1683.	7.31	-0.008	10.65	-0.062	30.69	-0.395	1110
** maize varieties **									
8sml	h-u	1299.	22.36	-0.133	28.39	-0.376	14.55	0.000	10
8sml	h-i	1921.	8.32	0.000	14.67	-0.269	29.38	-0.491	120
8sml	l-i	1931.	8.14	0.000	8.94	-0.149	32.49	-0.535	120
8sml	l-u	1477.	5.88	0.000	7.49	0.000	3.70	0.000	1670

TABLE A.5: JOWAR

ZONE	VARIETY- IRRIG./UNIRR.	ESTIMATED COEFFICIENTS OF THE YIELD RESPONSE FUNCTION y= a0 +a1*N +a2*(N**2) +b1*P +b2*(P**2) +c1*K +c2*(K**2) a0	a1	a2	b1	b2	c1	c2	NUMBER OF REPLIC.
jowar									
2mb	h-i	1577.	2.37	0.000	15.61	-0.189	26.93	-0.378	550
2mb	h-u	1485.	4.39	0.000	15.94	-0.120	4.99	0.000	190
jowar									
3mb11	l-u	735.	0.00	0.000	0.00	0.000	5.15	-0.110	0
3mb11	l-i	1265.	2.55	-0.001	5.58	-0.044	15.35	-0.803	0
jowar									
3mb31	h-u	745.	3.04	-0.007	6.47	-0.003	2.94	-0.014	1430
3mb31	l-u	620.	2.28	-0.004	7.53	-0.042	5.29	-0.054	830
jowar									
3mb11*	l-i	854.	1.92	-0.004	6.51	-0.052	0.47	0.000	0
3mb11*	dry	546.	7.40	0.000	11.02	0.000	5.27	0.000	120
jowar									
3mb31*	h-i	784.	2.06	0.000	9.62	-0.082	4.73	-0.048	1050
3mb31*	h-u	1370.	1.76	0.000	15.22	-0.143	-0.87	0.000	70
3mb31*	l-i	678.	1.95	-0.008	4.36	-0.038	4.05	0.003	660
jowar									
3mb3*	h-i	784.	2.06	0.000	9.62	-0.082	4.73	-0.048	1050
3mb3*	h-u	1370.	1.76	0.000	15.22	-0.143	-0.87	0.000	70
3mb3*	l-i	678.	1.95	-0.008	4.36	-0.038	4.05	0.000	660
3mb3*	dry	546.	7.40	0.000	11.02	0.000	5.27	0.000	120
jowar									
3mb4*	h-i	1208.	9.52	-0.049	1.75	0.000	3.79	0.000	160
3mb4*	h-u	1267.	4.51	-0.012	3.69	0.000	-0.16	0.000	40
3mb4*	dry	342.	0.83	0.000	4.35	0.000	3.33	0.000	70
jowar									
3rl*	h-i	2077.	8.70	-0.017	18.62	-0.207	7.54	0.000	310
3rl*	dry	1030.	5.15	-0.024	3.22	0.000	1.78	0.000	110
jowar									
4rbl*	h-u	1030.	5.15	-0.004	3.22	0.000	1.78	0.000	110
4rbl*	l-u	753.	3.73	-0.000	2.88	-0.006	1.27	0.000	100

TABLE A.6: BAJRA

ZONE	VARIETY- IRRIG./UNIRR.	ESTIMATED COEFFICIENTS OF THE YIELD RESPONSE FUNCTION y= a0 +a1*N +a2*(N**2) +b1*P +b2*(P**2) +c1*K +c2*(K**2) a0	a1	a2	b1	b2	c1	c2	NUMBER OF REPLICAT.
**bajra									
1d2	h-i	529.	4.32	0.000	2.76	0.000	6.68	-0.031	90
1d2	dry	1144.	5.99	-0.005	2.75	-0.004	3.82	0.000	410
**bajra									
2a	h-i	1747.	26.40	-0.074	9.95	0.000	1.17	0.000	60
2a	h-u	813.	55.55	-0.459	14.67	0.000	-2.44	0.000	20
2a	dry	813.	55.55	-0.459	14.67	0.000	-2.44	0.000	20
2a	l-i	1680.	13.14	-0.094	15.47	-0.316	0.04	0.000	110
2a	l-u	813.	55.55	-0.459	14.67	0.000	-2.44	0.000	20
**bajra									
2csl	h-i	2118.	3.93	0.000	17.81	-0.127	3.18	0.000	50
2csl	h-u	1882.	4.71	0.000	7.25	-0.044	1.03	0.000	100
2csl	dry	1882.	4.71	0.000	7.25	-0.044	1.03	0.000	100
2csl	l-i	1007.	8.39	-0.016	7.55	0.000	1.11	0.000	170
2csl	l-u	1271.	11.24	-0.028	7.86	0.000	-0.38	0.000	80
**bajra									
2go	h-i	1266.	6.15	0.000	5.04	-0.004	8.99	0.000	40
2gb	h-u	1144.	5.99	-0.005	2.75	-0.004	3.32	0.000	410
2go	dry	1144.	5.99	-0.005	2.75	-0.004	3.82	0.000	410
2go	l-i	995.	4.87	0.000	6.97	0.010	8.38	0.000	50
2go	l-u	906.	5.37	-0.005	4.97	-0.041	2.47	0.000	310
**bajra									
2mo	h-u	1600.	6.26	-0.008	18.95	-0.152	3.68	0.000	410
2mo	dry	1051.	8.34	0.000	20.60	0.000	6.11	0.000	360
2mb	l-u	592.	3.85	0.000	8.15	0.000	-0.55	0.000	640
**bajra									
3mcll	h-u	1600.	6.26	-0.008	18.95	-0.152	3.68	0.000	410
3mbll	dry	1051.	8.34	0.000	20.60	0.000	6.11	0.000	360
**bajra									
3mb4	h-u	1600.	6.26	-0.008	18.95	-0.152	3.68	0.000	410
3mb4	h-u	1051.	8.34	0.000	20.60	0.000	6.11	0.000	360
**bajra									
3gb	h-i	2215.	3.53	-0.004	5.97	-0.035	-0.12	0.000	180
3gb	h-u	1741.	3.73	0.000	6.83	0.000	0.85	0.000	940 -
3go	dry	1741.	3.73	0.000	6.83	0.000	0.85	0.000	940
3go	l-u	1071.	2.10	0.000	6.81	-0.031	12.04	-0.280	120
**bajra									
3rdol	h-i	999.	5.58	0.000	11.61	-0.070	5.41	0.000	290
3rdol	l-i	964.	7.70	-0.010	2.37	-0.003	0.79	0.000	270
**bajra									
3rca	dry	605.	3.72	-0.041	5.11	0.000	3.85	0.000	48
3rca	h-u	605.	3.72	-0.041	5.11	0.000	3.85	0.000	48

TABLE A.7: GROUND NUT

	VARIETY-	ESTIMATED COEFFICIENTS OF THE YIELD RESPONSE FUNCTION y= a0 +a1*N +a2*(N**2) +b1*P +b2*(P**2) +c1*K +c2*(K**2)							NUMBER OF
ZONE	IRRIG./UNIRR.	a0	a1	a2	b1	b2	c1	c2	REPLICAT.
**ground nut									
2mo	h-i	1018.	13.35	-0.065	28.26	-0.481	10.15	0.000	230
2mo	h-u	884.	21.27	-0.227	49.61	-1.029	6.32	0.000	20
2mo	l-i	465.	2.81	-0.035	2.69	-0.022	2.16	-0.016	170
2mo	l-u	287.	3.81	-0.026	6.03	-0.063	4.43	-0.075	80
**ground nut									
3moll	dry	1094.	8.90	0.000	3.96	-0.003	0.79	0.000	770
3moll	l-i	1692.	10.90	0.000	9.10	-0.046	5.93	-0.027	90
**ground nut									
3mo21	h-i	1936.	37.26	-0.563	9.53	-0.114	4.11	0.000	60
3mo21	dry	1094.	8.90	0.000	3.96	-0.003	0.79	0.000	770
**ground nut									
3rca	h-i	1338.	23.98	-0.308	6.11	0.000	2.76	0.000	130
3rca	h-u	1429.	5.23	0.000	8.52	-0.057	1.53	0.000	190
**ground nut									
4moll	h-u	1842.	6.71	0.000	0.21	0.000	3.46	0.000	50
4moll	l-i	1700.	13.80	-0.098	8.02	-0.078	14.28	-0.191	410
4moll	l-u	657.	10.47	-0.071	7.27	-0.026	2.57	0.000	110

TABLE A.8: COTTON

ZONE	VARIETY- IRRIG./UNIRR.	ESTIMATED COEFFICIENTS OF THE YIELD RESPONSE FUNCTION y= a0 +a1*N +a2*(N**2) +b1*P +b2*(P**2) +c1*K +c2*(K**2) a0	a1	a2	b1	b2	c1	c2	NUMBER OF REPLICAT.
**cotton									
2csl	h-i	1140.	4.90	-0.007	0.62	0.070	0.43	0.030	90
2csl	h-u	1270.	3.12	-0.002	2.03	0.000	1.64	0.000	30

TABLE A.9: GRAM

ZONE	VARIETY- IRRIG./UNIRR.	ESTIMATED COEFFICIENTS OF THE YIELD RESPONSE FUNCTION y= a0 +a1*N +a2*(N**2) +b1*P +b2*(P**2) +c1*K +c2*(K**2) a0	a1	a2	b1	b2	c1	c2	NUMBER OF REPLICAT.
**gram									
4mb2	h-u	1065.	25.08	-0.254	16.28	-0.115	3.99	0.000	260
4mb2	dry	489.	12.98	-0.141	4.55	-0.028	1.94	0.000	90