Evaluation of soil tests for N Requirement of maize

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Abstract

Soil test methods for nitrate–N, total N and organic C were evaluated in the greenhouse, using 20 soils mostly from farmer's fields, in Nigeria. The results indicated that NO_3 –N was the best index of available N for a short 4–week period but the poorest under continuous cropping over eight weeks. Total N and organic C values were superior to nitrate–N on long cropping system.

The three soil Nitrogen indices were also evaluated and caliberated in a field study on five bench mark soils for two seasons. The results indicated that NO_3 N was correlated significantly with total N and organic C, and these were in turn correlated with relative yield in the field. Deficiency values were 20 ppm No_3–N, 0.11% total N and 1.26% C. Organic C and total N were highly correlated for the soils; therefore it is possible to use either organic C or total N values for predicting response of crop to N application.

Introduction

Nitrogen is the most limiting nutrient for cereal crops in Nigeria. N or organic matter status has been arbitrarily used to determine the maize requirements of N. Maize requires 25–40kgN/ per ha (Sobulo, 1982) in the forest zones to 100 – 120 KgN/ha in the savanna, (Jones, 1974, Balaaubramanian et al., 1978), equivalent to ¼ – 3/5 t ha^{-1} Urea. The high cost of fertilizers and the current economic recession in Nigeria make it necessary to find sound bases for rational application of fertilizers to crops. Mineral nitrogen, unlike phosphate, is easily leached and therefore transient and may be a poor index of available N to maize with an active growing period of about three months in the field and under very humid climate.

Organic matter content of 2% has been considered a critical level above which N response is small (Agboola and Corey, 1973; Agboola and Obigbesan, 1974). Total N has been established as an index of available N in the tropics and a value of 0.16% is required for 95% relative yield (Warmsley and

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Baynes, 1974). Organic matter and total N indices, which are fairly stable in the soil, have wider use in the tropics than mineral N. Sobulo *et al* (1975, 1977) reported NO_3–N as a better index for available N than either organic C and total N for tomatoes and upland rice. In the temperate environments, however, NO_3–N has been successfully used for assessing N requirements on soil sampled to about 30 – 60cm depth, (Smith, 1966; spencer *et al.* The purpose of this study was to assess Nitrate–N, total N and organic C methods as indices of N availability to maize. These parameters are considered easy to measure and adaptable to routine and rapid analysis (Ataga *et al.*, 1981; Sharrawat, 1982; 1983; Waring and Bremier, 1964).

Materials and Methods

Twenty surface soils (0 – 15cm) representing typical soils on which maize is grown in Nigeria were used in this study. These soil samples were mainly from farmers' plots and field trial sites under forest and savanna vegetation.

After air-drying and sieving with a 2mm sieve, 2 Kg of each soil was weighed into plastic pots. Basal dressings of major and minor elements except nitrogen were mixed thoroughly with the soil in the following amounts: 100mgK, 100mgMg, 100 mgCa, 10 mgZn, 10 mgFe, 25 mgMn, 2 mgB, 0.5 mgMo and 5 mgCu per pot of 2 kg soil. (Osiname, unpublished). Each treatment was replicated three times and the pots were arranged randomly on the greenhouse bench. Watering of the pots was done daily with about 50 mls distilled water. The maize tops were harvested after twenty-eight days, oven dried at 80°C for 24 hours, weighed, ground and stored for analysis.

The experiment was repeated for another twenty-eight days on the same soil with additional basal nutrients added.Soil sampling was done before the cropping.

Field Trial

The field trials were carried out in five locations covering the major ecological zones of South-Western Nigeria. The locations are Ilora, Ilorin Akure, Agbede Farm, Auchi and Ikenne. The field trials were carried out for the period of three years. Randomised block design with three replicates was used and six rates of N viz: 0, 30, 60, 90, 120 and 150 Kg/ha as urea were applied. Each plot size was 5m x 3m,made up of three rows. The zero treatment received all the basal nutrients except nitrogen. Harvesting was done at the end of each season. Maize was dehusked and weighed. The relative yield percentage was calculated as

$$RY = \frac{\text{Yield without N}}{\text{Maximum yield with N}} \times \frac{100}{1}$$

Soil Analysis

Available nitrogen in the soils was evaluated by the following methods:

Total nitrogen:	1g ground soil was digested with concentrated H_2SO_4 for 3½ hours (Kjeldahl method). Nitrogen was determined with Auto-Analyser as ammonium nitrogen.
Water solube NO_3–N	5g of soil was extracted with 25 mls distilled water and NO_3–N determined by the phenol disulfonic acid methods.
Organic carbon method:	0.5g soil oxidised with a mixture of H_2SO_4 and 1N potassium dichromate with diphenylamine as indicator and titrated with ferruous ammonium sulphate.

Statistical Analysis

Matrix correlations of Total N(micro-Kjedahl), organic carbon (Walkley and Black, 1954), and NO_3–N (phenol disulfonic acid method) with dry matter yield, N%, plant uptake, cumulative dry matter yield and the cumulative uptake in the greenhouse were computed. Matrix correlations was also conducted on the field trial data. Field results were evaluated to determine the critical soil N level for N availability indices values.

Results and Discussion

The results of initial analysis of soils in the greenhouse study is contained in Table 1. The soils have wide pH range with a mean of 6.11. The soils have generally coarse texture but savanna soils have greater sand content than soils in forest zone. Organic matter levels is also higher in the forest than in the savanna soils. The mean initial nitrogen status is 0.07% total N and 29 ppm NO_3–N. Table 2 contains correlation between amount of nitrogen extracted by various methods and crop response to N expressed as dry matter yield, %N in plant and N uptake in the greenhouse study. Soil

Table 1: SOME PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL USED FOR THIS STUDY

	Mean	Range
pH (water)	6.11	5.30 – 7.00
Sand %	85.30	73.00 , 3.00
Silt %	11.50	3.00 – 5.00
Clay %	3.20	2.00 – 8.00
Available P ppm (Bray I)	3.96	0.70 – 4.85
Exchangeable K (me/100g)	0.22	0.69 – 1.01
CEC (mel 100g)	5.75	3.32 – 0 61
1st Crooping		
Organic carbon %	1.05	0.57 – 1.49
Total N%	0.07	0.04 – 0.19
NO_3–N ppm	29.08	14.0 – 4.40
2nd Cropping		
Organic carbon %	0.77	0.10 – 1.9
Total N%	0.07	0.03 – 0.1
NO_3–N ppm	20.36	11.40 – 33.60

Table 2: CORRELATION BETWEEN AMOUNT OF N EXTRACTED BY VARIOUS METHODS ESTIMATED YILED, %N IN PLANT AND N SPEARE

Extractant	1st Cropping			2nd Cropping			Cumulative	Cumulative
	Drymatter yield (gm)	%N in plant	Uptake	D.M. yield	%N in plant	Uptake	D.M. Yield (1st + 2nd)	uptake (1st + 2nd)
Total N %	0.320	0.385	0.403	0.237	0.415	0.257	0.753*	0.674**
Organic carbon %	0.434	0.292	0.395	0.214	0.214	0.219	0.693**	0.571**
NO_3–N pp in	0.350	0.510*	0.413*	0.619**	0.298	0.714**	0.213	0.427

** Significant at 1% level.

* Significant at 5% level.

NO_3–N gave the best correlation with %N in the plant and uptake in the short cropping cycle. Similarly, NO_3–N also gave best correlation with dry matter yield and N uptake at end of second harvest. The correlation in the second harvest was higher because there was less consumption since soil N (NO_3–N) has been reduced considerably by the first crop in many soils, (Figs. 1 and 2). However the reverse was the case when initial soil N indices were correlated with cumulative values of yield and N uptake (Table 2, Figs. 3 and 4). Multiple correlation of two indices with crop availability index (cumulative yield and uptake) are contained in Table 3. The result indicated that carbon and total N combined gave a better correlation with yield or uptake than organic carbon or total N alone. Total N and NO_3–N combined gave the same correlation as total N alone. This indicated that total N alone is adequate for predicting dry matter yield.

Carbon plus NO_3–N is only slightly better than carbon alone as index of N availability. Field studies also indicated that NO_3–N was the best single index for predicting yield, (Table 4, Figs. 5, 6 and 7).

Soil Test calibration for maize

Cate/Nelson graphical method was used to determine critical nutrient levels. The results indicated that total N and organic carbon gave a linear relationship with relative yield while the relationship with NO_3–N is quadratic (Figs. 5, 6 and 7) with a higher correlation coefficient than the other two indices. Field data showed that significant response was obtained to nitrogen at 50% relative yield while response was small and uneconomic at 90% relative yield. There is therefore justification to relate 'deficiency' and 'sufficiency' levels of soil nitrogen indices of available N, total N below 0.05% and 0.11% are 'deficient' and 'critical' value respectively. The corresponding values for organic carbon are 0.70 and 1.26% while that of NO_3–N is 20 ppm and 30 ppm (Figs. 5, 6 and 7). The usefulness of any soil test yield calibration study depends on practical recommendations that could be made from it. Robinson (1968) have classified soil tests into three or more groups. In this study, two classes will be recommended, 'deficient' and 'critical'. The current optimum recommended fertilizer level should be applied to deficient soils, and one third of the optimum level for soils above critical level as an insurance against an error in soil test assesment and also as maintenance dressing. The 0.11% total N found as critical for the maize crop in south western Nigeria is in agreement with the results of previous study in Nigeria, (Sobulo, 1980). The corresponding carbon was 1.40% close to the 1.26% obtained in this study. Warmsley and Baynes

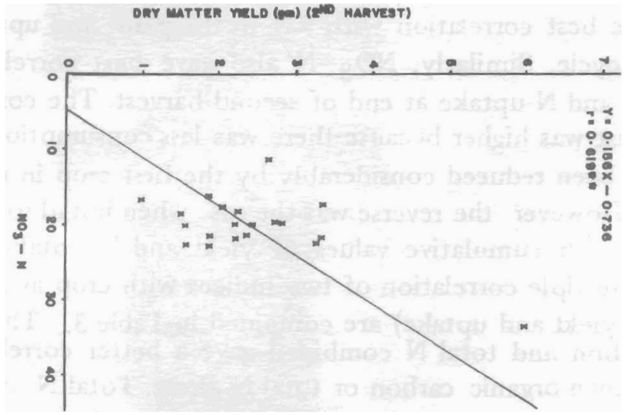

Fig. 1: RELATIONSHIP BETWEEN NO_3–N METHOD AND DRY MATTER YIELD (2ND HARVEST)

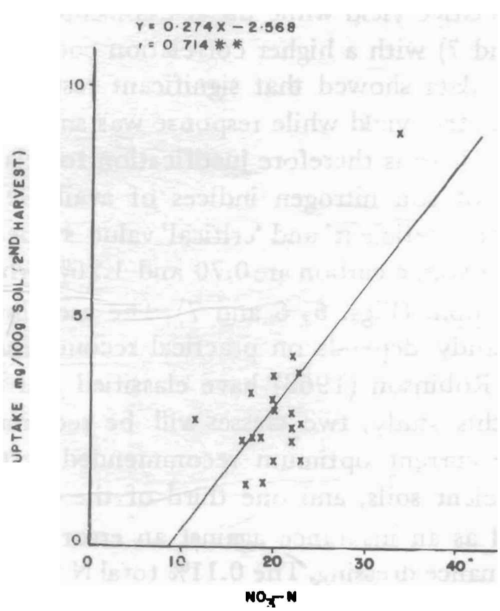

Fig. 2: RELATIONSHIP BETWEEN NO_3–N METHOD AND UPTAKE (2ND HARVEST

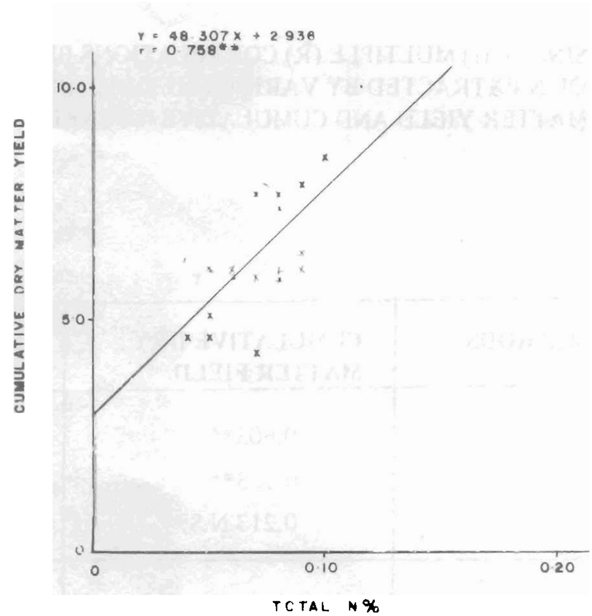

Fig. 3: RELATIONSHIP BETWEEN TOTAL N % AND CUMULATIVE DRY MATTER YIELD

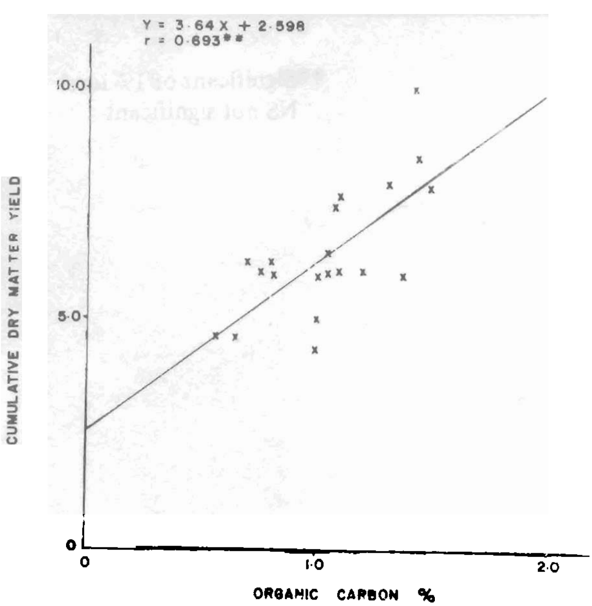

Fig. 4: RELATIONSHIP BETWEEN ORGANIC CARBON % AND CUMULATIVE DRY MATTER YIELD

Table 3: SINGLE (r) MULTIPLE (R) CORRELATIONS BETWEEN AMOUNT OF N EXTRACTED BY VARIOUS METHOD, CUMULATIVE DRY MATTER YIELD AND CUMULATIVE UPTAKE

	r	
METHODS	**CUMULATIVE DRY MATTER FIELD**	**CUMULATIVE UPTAKE**
Organic carbon	0.603**	0.571**
Total N	0.758**	0.674**
NO_3–N	0.213 N.S.	0.427 N.S
	R	
Carbon + Total N	0.775**	0.677
Total N + NO_3–N	0.758**	0.724
Carbon + NO_3–N	0.708**	0.684

**Significant of 1% level
NS not significant

Table 4: CORRELATION BETWEEN SOIL N INDEX AND RELATIVE YIELD

Methods	**50% relative yield deficient level**	**90% relative yield critical level**	**Relative yield correlation co-efficient (R)**	**Regression equation**
Total N%	0.05	0.11	0.544*	$Y = 373.22X + 30.0$
Organic carbon %	0.70	1.26	0.555*	$Y = 44.16X + 16.43$
NO_3–N ppm	20	30	0.730–	$Y = 0.20^{X2} - 5\ 46X + 81.76$

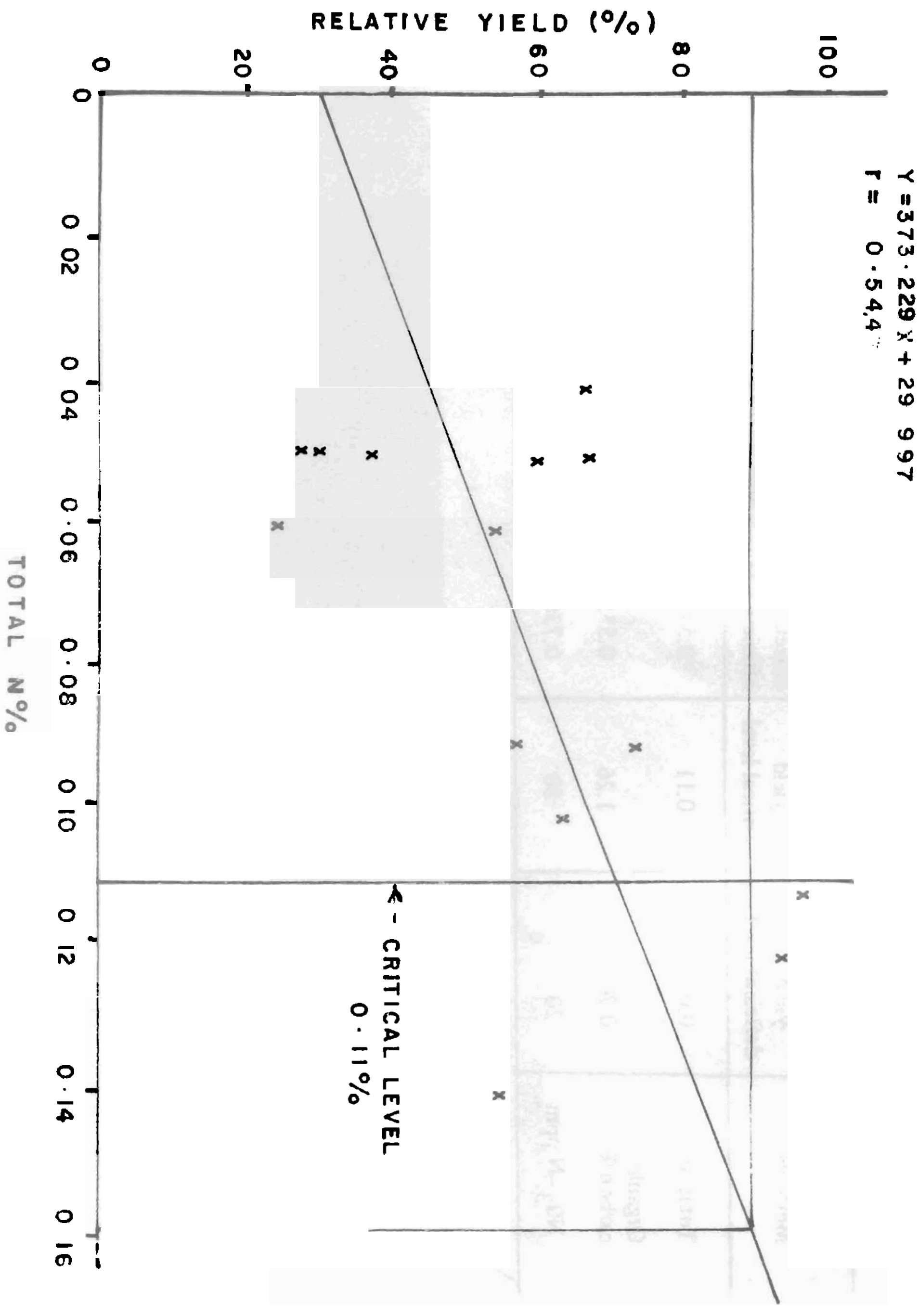

Fig. 5: RELATIONSHIP BETWEEN RELATIVE YIELD AND TOTAL N

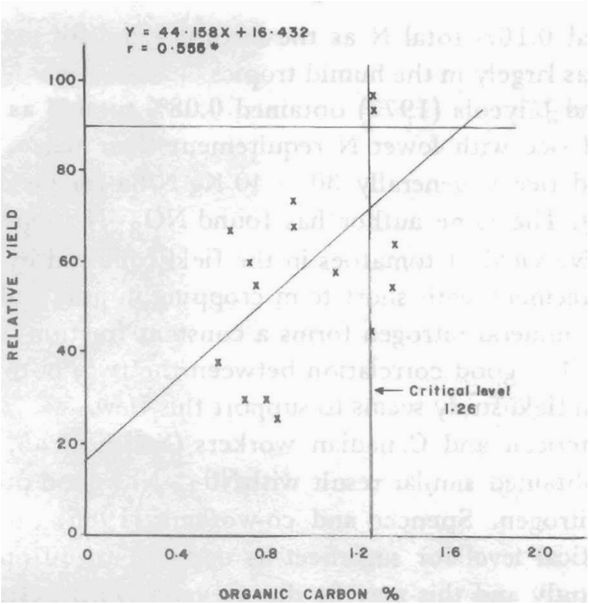

Fig. 6: RELATIONSHIP BETWEEN RELATIVE YIELD AND ORGANIC CARBON IN THE FIELD

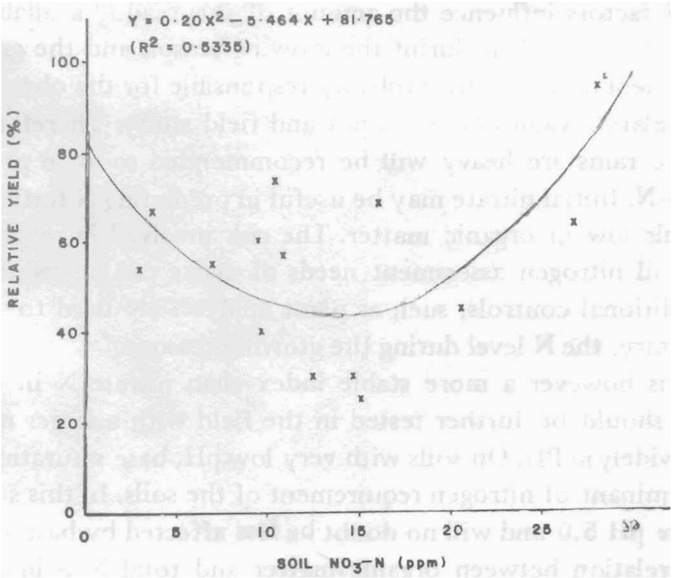

Fig. 7: RELATIONSHIP BETWEEN RELATIVE YIELD AND NO_3–N IN THE FIELD

(1974) obtained 0.16% total N as the critical value for maize in the West Indies which was largely in the humid tropics.

Sobulo and Jaiyeola (1977) obtained 0.08% total N as critical level in soil for upland rice with lower N requirement than maize. The N requirement of upland rice is generally 30 – 40 Kg N/ha for yield of 2 – 3 t/ha (Sobulo, 1977). The same author has found NO_3–N to give best relationship with relative yield of tomatoes in the field followed by organic carbon which is in agreement with short term cropping in pots and in the field in this study. The mineral nitrogen forms a constant fraction of organic nitrogen in the soil. The good correlation between the two, both for greenhouse soils and soils in field study seems to support this view.

Some American and Canadian workers (Smith *et al.*, 1966; Spencer *et al.*, 1966) obtained similar result with NO_3 –N as good predictor of crop response to nitrogen. Spencer and co-workers (1966) obtained 60 ppm NO_3–N as critical level for sugarbeet as opposed to 30 ppm NO_3–N for maize in this study and this may be due to variation in relative nitrogen requirements of different crops and yield levels of the crop. However, there is no data on the suitability of NO_3–N as an index of available N to maize crop in Nigeria.

In the field however, climate, soil temperature, soil moisture and other environmental factors influence the amount of this readily available N that will be released to the plant durint the growing season and the grain yield. These environmental effects are probably responsible for the observed differances in correlation values between pot and field study. Therefore, timely planting before rains are heavy will be recommended so as to prevent leaching of NO_3–N. Initial nitrate may be useful in predicting N fertilizer needs in savanna soils low in organic matter. The risk involved in relying mainly on available soil nitrogen assessment needs of maize can be reduced considerably if additional controls, such as plant analyses are used to assess and adjust if necessary, the N level during the growing seasons.

Total N is however a more stable index than nitrate N in long term cropping and should be further tested in the field with a larger number of sites varying widely in PH. On soils with very low pH, base saturation may be a strong determinant of nitrogen requirement of the soils. In this study most of the soils are pH 5.0 and will no doubt be less affected by base saturation. The good correlation between organic matter and total N is in agreement with other results for tropical soils and any of them can be used. It is worth noting that multiple correlation of the two is slightly better than either alone.

The curvillinear relationship between NO_3–N and relative yield in field study was partly due to denitrification of native soil NO_3–N under transient water logging caused by high rainfall conditions in the field. This therefore explains the better relationship in greenhouse which is better controlled than field conditions.

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