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PRELIMINARY EVALUATION OF PROMISING LINES OF COMMON BEAN (*Phaselus vulgaris* L.) FOR EARLY SOWINGS IN MELENA DEL SUR

Evaluación preliminar de líneas de frijol común (*Phaselus vulgaris* L.) promisorios para siembras tempranas en Melena del Sur

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ASBTRACT. Common bean in Cuba is part of the basic food of population but their yields are not sufficient for self-supply due to the varied conditions in which this legume is grown and poor of cultivars adapted to these environments. This study was conducted in areas of the farm "Santovenia", located in the municipality "Melena del Sur". The objective of this work was to evaluate the agronomic performance of 15 lines of common bean, introduced in the collection of Local Agricultural Innovation Project (PIAL, according its acronyms in Spanish) that develops at the National Institute of Agricultural Sciences (INCA). Sowing was done in the first half of September 2013, in a randomized block design and including the commercial cultivar Cuba Cueto 25-9N (CC 25-9N) as reference. It was observed that genotypes in general study showed significant differences in the days to flowering, days to harvest maturity, number of pods per plant and yield. The plant height and number of grains per pods do not allow discriminating between the lines. All lines showed a shorter life cycle than the commercial variety, this allows escaping from drought. The comprehensive analysis of the results allowed proposing to the lines MH 43-2, MEN 2202-16, MER PRO 0334-126 and 2222-48 as the best performing of group, so they can be introduced into the productive practice.

Key words: season, yield, genotypes, varieties

RESUMEN. El frijol común en Cuba forma parte de la alimentación básica de la población pero sus rendimientos no son suficientes para el autoabastecimiento debido entre otras cuestiones, a las variadas condiciones en que se cultiva esta leguminosa y la mala distribución de cultivares adaptados a esos ambientes. El presente estudio se realizó en áreas de la finca ´Santovenia´, ubicada en el municipio ´Melena del Sur´ con el objetivo de evaluar el comportamiento agronómico de 15 líneas de frijol común, introducidas en la colección del Proyecto de Innovación Agropecuaria Local (PIAL) que se desarrolla en el Instituto Nacional de Ciencias Agrícolas (INCA). La siembra se realizó en la primera quincena de septiembre de 2013, en un diseño de bloques al azar e incluyendo el cultivar comercial Cuba Cueto 25-9N (CC 25-9N) como referencia. Se observó que los genotipos en estudio mostraron en general diferencias significativas en cuanto a los días a la floración, días a la madures de cosecha, el número de vainas por plantas y rendimiento. La altura de la planta y número de granos por vainas no permiten discriminar entre las líneas. Todas las líneas mostraron un ciclo biológico más corto que el cultivar comercial lo que les permite escapar de la sequía. El análisis integral de los resultados, permitió proponer a las líneas MH 43-2, MEN 2202-16, PRO 0334-126 y MER 2222-48 como las de mejor comportamiento del grupo, por lo que pueden ser introducidas en la práctica productiva.

Palabras clave: época, genotipos, rendimiento, variedades

INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is the most important legume in the tropics of Latin America and eastern and southern Africa; it is usually grown by small farmers in these regions (1).

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This legume is a fundamental dish in the diet of Cubans, where grains, rice with milk, black beans that make up the typical food of the population. However, the country has been importing 60 thousand tons of grain per year to meet market demand, which amounts to more than 52 million dollars, which puts the food security of the population at risk due to the disbursement of large amount of foreign currency (2).

Due to the high cost of beans in the market and the high demand of beans in the population, strategies to increase yields and reduce imports are followed in Cuba, for which large areas of land have been allocated both in the state sector and in farmers' farms, followed by the implementation of actions in order to promote the production of seeds, the improvement of varieties, among others.

To this end, it is necessary to have improved varieties or not, which contribute to the increase of these yields for their better adaptation to the diverse agroecosystems in which legumes are cultivated (3), since they generally develop in environments with low availability of agrochemical inputs and energy, so beans produced by farmers are more vulnerable to stress caused by biotic and abiotic factors.

In Cuba, for the cultivation of beans, the period between September and January has been reported as the sowing season, within this period are considered as the ones framed in September that (4), in general, they are used by farmers who do not have irrigation systems, who take advantage of the residual moisture provided by the last rainfall during the rainy season. In these growing conditions, frequently, at the end of the life cycle of some varieties, periods occur that negatively influence yield. This is because it has been established of varieties adapted to the systems of cultivation under irrigation but no genetic material of beans has been found that is identified by its level of tolerance to water stress (5).

Melena del Sur municipality, located in the Mayabeque province, constitutes a territory of great importance in the country not only because of its history and socioeconomic development; in particular, by agricultural production (6). The diversity of crops grown in the municipality supports the feeding of the capital's population, which makes it necessary to strengthen agricultural production with alternatives that are easily accessible to producers, with the introduction of new bean cultivars, which have qualities desirable for the conditions of the territory, a variant that is of great importance to raise the yields of this legume. For this, a thorough study of available germplasm is indispensable, in order to recommend for production, those that possess, in addition to a good response to diseases, an adequate productive response.

For the foregoing, the objective of the present work was, to evaluate the agronomic response of different advanced bean lines under conditions of early sowing in Melena del Sur municipality.

MATERIALS AND METHODS

Vegetal material

The plant material of the research consisted of 15 advanced lines of black grain color, from the Agricultural School of Zamorano, in addition, the commercial cultivar Cuba Cueto 25-9N (CC 25-9N) was used by the owner of the plant of the farm where the experiments were developed (Table I).

Table I. Advanced lines belonging to an Ecological Adaptation and Performance (ECAR) of black grain color used in the study

No	Línea o cultivar	Procedencia
1	PRO 0334- 126	PIF
2	MH 43- 2	PIF
3	MEN 2202- 16	PIF
4	MER 2222- 48	PIF
5	BCN 20- 05- 73	PIF
6	MH 59- 3	PIF
7	XRAV 68- 1	PIF
8	RBF 14- 54	PIF
9	RBF 14- 34	PIF
10	XRAV 187- 3	PIF
11	X02 33- 153	PIF
12	RBF 11- 60	PIF
13	X02 33- 147- 2	PIF
14	X02 33- 159- 2	PIF
15	DOR 390 (TU)	PIF
16	Cuba Cueto 25-9N	IIGranos

PIF (Programa de investigación del frijol en Honduras), IIGranos, Instituto de investigaciones de granos

These lines entered Cuba through the Local Agricultural Innovation Project (PIAL according to its acronyms in Spanish) led by the National Institute of Agricultural Sciences (INCA) to be evaluated in local conditions and subsequently released to contribute to the strengthening of agricultural production systems of the current Cuban context.

Location and duration of the experiment

The experiment was carried out in the period from September to December 2013, at the 'SANTVENIA' farm, located in the Melena del Sur municipality, in the Mayabeque province. The soil of the farm was classified as a typical Red Ferralitic, according to the Classification Version of the Soils of Cuba (7).

Description of the experiment and agronomic management

The preparation of the soil was done with animal traction, fertilization and other cultural work of the area was carried out as established in the technical guide for the production of the bean crop (4).

The planting was done in plots of 7,2 m² with four rows (rows) separated at a distance of 0,60 m and a distance between plants of 0,10 m for a planting density of 16666 plants per hectare. Before sowing, Azofert® was applied to the seed and they were pelleted with EcoMic® at a rate of 200 mL ha^{-1} and 5 kg ha^{-1} respectively. The distribution of both products was manually.

During the experiment development, no irrigation was applied and the moisture left by the precipitation from a previous day for sowing was used. The historical behavior of the climatic variables average, maximum and minimum temperature and rainfall in the municipality in the territory was taken into account (8) (Figure).

Experimental variables

The variables evaluated in the field were morphological and phenological: height of the plant (AP), days to flowering (DF), and days for harvest maturity (DMC). At the time of harvest, the yield variables and their components: number of pods per plant (NVP), number of grains per pod (NGV) and yield (Rend.) In kg ha^{-1} at 14 % humidity, according to what is established by the International Center for Tropical Agriculture (CIAT) for the cultivation of beans (9).

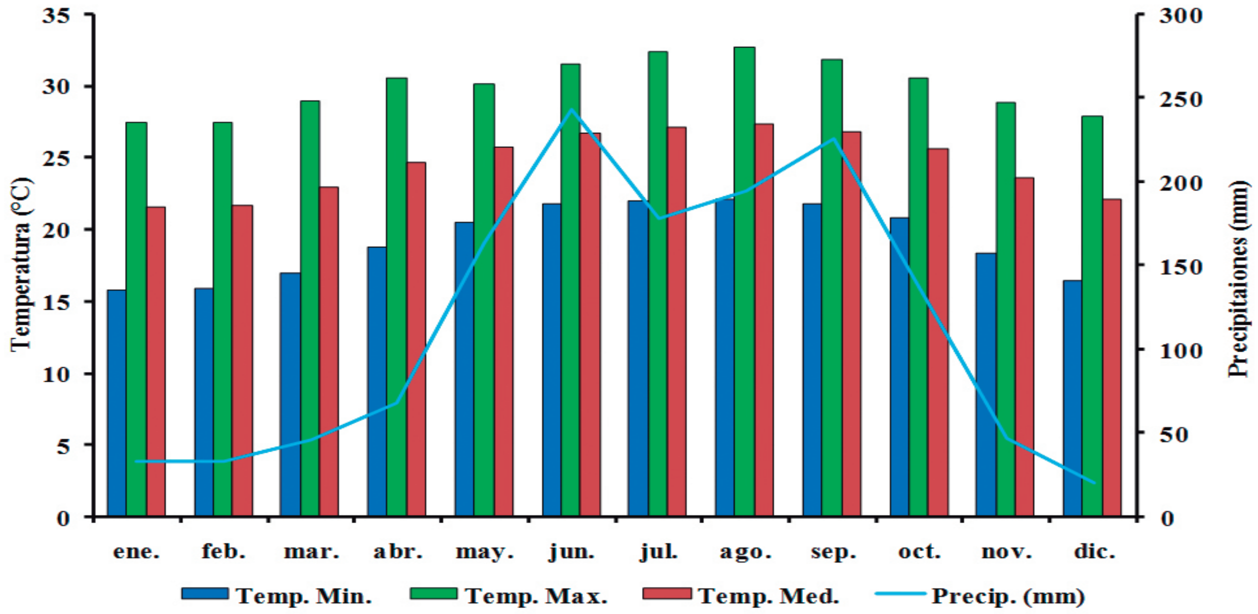
Statistical analysis and experimental design

A randomized block experimental design with three replicates was used. For the statistical analysis, after checking the theoretical assumptions of normality and homogeneity of the variance, the software SPSS/PC+ ver. 19.0 (10), with analysis of double classification variance for each variable evaluated and to verify the significant differences between treatments (lines) a test of multiple ranges of Tukey for $p \leq 0,05$ (11).

RESULTS AND DISCUSSION

Response of morphological and phenological variables

Table II shows the behavior of the variables evaluated during the development of the crop of the 15 lines as well as the commercial cultivar CC 25-9 N under conditions of early season under residual humidity.



Source: climate-data.org

Figure. Historical behavior of climatic variables (temperature and rainfall) in Melena del Sur municipality, Mayabeque

Table II. Variables evaluated during the development of the crop

Líneas	DF	DMC	AP (cm)
PRO 0334- 126	35,33 c	78,00 a	42,00
MH 43- 2	35,67 c	76,00 a	28,33
MEN 2202- 16	38,33 bc	79,33 ab	52,67
MER 2222- 48	38,67 bc	77,67 a	32,33
BCN 20- 05- 73	42,0 ab	78,00 a	31,67
MH 59- 3	37,67 bc	76,33 a	35,33
XRAV 68- 1	37,00 c	77,33 a	29,67
RBF 14- 54	35,33 c	78,00 a	29,33
RBF 14- 34	35,00 c	77,00 a	26,00
XRAV 187- 3	35,67 c	77,00 a	26,67
X02 33- 153	38,33 bc	77,33 a	35,33
RBF 11- 60	37,67c	77,00 a	25,67
X02 33- 147- 2	37,00 c	77,33 a	31,00
X02 33- 159- 2	35,33 c	77,33 a	39,00
DOR 390 (TU)	37,33 bc	78,67 ab	42,67
CC-25 - 9N	44,67 a	83,00 b	40,67
DE	2,87	2,02	1,66
CV (%)	7,65	2,6	33,26
P	0,0001***	0,0029**	0,16 ns

AP (Plant height), DF (Days to flowering), DMC (Days to harvest maturity), DE (Standard deviation), CV (Coefficient of variation), p (Probability for p≤0.05), ns (Not significant), *** (significant at p≤0.001), ** (significant at p≤0.01) *** (significant at p≤0.001) ***

The days to flowering in the genotypes evaluated showed significant differences in the ANOVA. This variable ranged between 35 and 45 days to reach 50 % of the plants observed with at least one flower completely open (9). The line that took fewer days to reach flowering was RBF14-34 that showed 35 DF.

It is important to note that, except for line BCN 20-05-73, all the lines evaluated showed highly significant differences (p = 0,0001) with the commercial cultivar CC 25-9 N that was needed, under the agroclimatic conditions in which they were evaluated, 44,6 days to reach 50 % of flowering plants.

The flowering is an element of great help for the agronomic management in the crops. Some authors refer that the days to flowering is a factor of consideration in the breeding process of the cultivars since it is necessary to look for the synchrony between the parents (12). On the other hand, other authors refer to take into account this variable at the time of making applications of some fertilizers and other products to control the appearance of pests (13), since these can cause a detrimental effect to flowers and affect performance, so it is necessary to evaluate them in the different cultivars that are proposed for the different agricultural systems.

The time to flowering can be seriously affected by the day length and the temperature; increasing the days to the flowering with low temperatures and short days, this can imply changes in the behavior of the materials according to zones and sowing seasons (14). Thus, differences have been reported in the biological cycle of different cultivars when planted in different sowing seasons, this being related to tolerance to high temperatures (15).

When evaluating the days to harvest, highly significant differences were established (p = 0,0029) between the genotypes evaluated and the commercial cultivar CC 25-9N with the exception of the lines MEN 2202-16 and DOR-390 (TU) that did not they differ from this (Table II). The values varied between 76 and 83 days after sowing in wet soil.

It was detected that all the evaluated lines needed less days (6-7 days) than the commercial cultivar CC 25-9N to reach 50 % of the plants observed with 90 % defoliation as established by CIAT for the evaluation of this character (9), which indicates that these lines could be useful for presenting the shortest cycle as a mechanism of evasion to environmental stresses that may persist in each culture environment (16). In this regard, the escape to drought has been defined, as the ability of crops to complete their life cycle before a serious deficit of water in the soil and the development of the crop. This mechanism involves rapid phenological development (flowering and early maturation), environmental plasticity (variation in the duration of the growth period depending on the water deficit degree) and mobilization of photosynthates to the grain (17).

Precocity is one of the characteristics most appreciated by Cuban farmers, since by using varieties with fewer days to harvest maturity, two crop cycles can be sowed in the same campaign and in some cases three cycles. In addition, for the sowing of the early season, where the residual humidity provided by rainfall is used as the main resource for irrigation, it is necessary that the varieties do not show a late maturation cycle, so that the most critical moments, referring to the need for water, are framed within the rainy period, which will allow them to take advantage of the humidity provided by rainfall.

It is important to note that under these agroclimatic conditions the commercial cultivar CC 25-9N presented a shorter cycle (83 days after sowing in wet soil) than that reported in the technical guide for the production of bean cultivation in Cuba (13). This response may be related to the behavior of the climatic variables that persisted in the period in which the experiment was developed (8).

Several authors have reported the incidence of climate on the performance of the phenology of the different varieties (14,18). In this regard, it has been suggested that the biological cycle of the common bean changes according to genotype and climate factors, and may last approximately 75-120 days (19).

The influence of low temperatures on the duration of the phenological phases has been reported, extending the vegetative cycle of the crop, where variations between 66 and 80 days have been detected to reach harvest maturity (18). Likewise, it has been reported that average temperatures above the maximum threshold for beans cause the shortening of the biological cycle of the different varieties (15).

The optimum temperatures for bean cultivation are considered to be 18 to 24 °C (20); however, the average historical and maximum temperatures reported for the months of September and October (average 27 and 26 °C and maximum and 32 and 31 °C respectively) (8), in the territory where this experiment was developed, they are slightly higher to the optimal ones required for the crop, which could have influenced the shortening of the biological cycle of the cultivar CC 25-9N (Figure).

In Table II, the average values obtained for each of the lines studied are presented when evaluating the height of the plant (AP) in cm of a sample of 20 plants. In the ANOVA applied to this variable it was detected that there were no significant differences (p = 0,16) between the genetic material evaluated. However, this variable ranged between 25,67 and 52,67 cm for the genotypes RBF 11-60 and MEN 2202-16, respectively.

It should be noted that the phenotypic expression of these characters can be determined by the environmental variations where the culture is developed (21).

Differences in plant height or stem length of each of the genotypes studied may be due to differences in the length between the internodes of each cultivar, which may be determined by the genetic characteristics, as well as by the effect it exerts the environment on the expression of this character in each of the cultivars (16).

On the other hand, the lack of differences in the height of the plants between the different lines and the cultivar CC 25-9 N, may be due to the lack of genetic diversity among them for this character, so we would have to continue investigating the lines evaluated through other morpho-agronomic, biochemical and molecular characters to analyze the existing variability, because it is necessary to have diversity in the farms to reduce biological vulnerability (22).

Response of performance and its components

Table III shows the performance variables and their components evaluated in the 15 lines and the cultivar CC-25-9 N. In the variable number of pods per plant in the genotypes studied, in general, there were statistical variations in the genetic material evaluated. In the ANOVA, it was observed that the lines evaluated did not differ statistically between them, in turn, all the lines showed statistical differences with respect to the cultivar CC 25-9N, indicating a greater adaptation of these lines to the conditions of early sowing under residual humidity, where high temperatures and high rainfall during the development of the crop are prevailing (Figure).

Table III. Evaluated variables of yield and its components in bean genotypes in early season conditions

GENOTIPOS	NVP	NGV	Rend. (kg ha^{-1})
PRO 0334-126	9,33 abc	5,33	1284 bcd
MH 43-2	9,33 abc	5,33	1302 bcd
MEN 2202-16	8,63 abc	5,37	1344 cd
MER 2222-48	8,87 abc	5,33	1491 d
BCN 20-05	8,27 abc	5	521 a
MH 59-3	7,7 abc	4,67	783 abcd
XRAV 68-1	10,63 bc	5	1082 abcd
RBF 14-54	10,77 bc	4,33	536 a
RBF 14-34	10,47 bc	4,33	565 ab
XRAV 187-3	8,23 abc	5,33	864 abcd
X02-33-153	6,63 abc	5	644 abc
RBF 11-60	11,37 c	5	735 abc
X02-33-147-2	6,93 abc	5,67	935 abcd
X02-33-159-2	10,33 abc	5	795 abcd
DOR-390 (TU)	6,90 abc	6	1048 abcd
CC 25-9-N	5,90 a	5,67	763 abcd
DE	2,04	1,08	363
CV (%)	23,25	20,78	40,7
P	0,0008***	0,94ns	0,0005***

NVP (number of pods per plant), NGV (number of beans per pod), Rend. (Performance)
DE (Standard deviation), CV (Coefficient of variation), p (Probability for p≤0.05), ns (Not significant), *** (significant at p≤0.001), ** (significant at p≤0, 01)

The NVP values ranged between 5,9 for the commercial cultivar CC 25-9 N, with the lowest number of pods produced by plants and 11,37 for the line RBF 11-60 that obtained the highest value of this variable.

This result shows the best behavior of these lines, which surpass the cultivar that the farmer has (CC 25-9N) in the agroclimatic conditions of early sowing.

It has been informed that the number of pods per plant can be determined to a large extent by the characteristics of each cultivar; however, the effect of environmental factors on them is an important aspect to be taken into account due to the variations that can be created in this character. Several authors think that the number of pods per plant is strongly related to the genetic characteristics of the plant, and that these can suffer affectations motivated by the climatic differences of one environment with respect to the other (21). These same authors state that the behavior patterns of the variable pods per plant differ significantly between genotypes with different plant architectures and growth habits depending on the effect of the environment.

There are several factors influencing the NVP that are categorized as reproductive and may vary according to environmental conditions. It has been reported that high temperatures increase the production of buds and flowers, but also the abscission of flower buds, flowers and pods (18), this may be one of the aspects that influenced the cultivar CC 25-9N to produce fewer pods in conditions of early sowings, thus, the lines under study, were more adapted to the climatic conditions for that time of sowing.

In the behavior of the number of grains per pods of the 16 genotypes evaluated under conditions of early sowings, it can be seen that there were no significant differences ($p = 0{,}94$) for this variable as in the plant height, which it can be indicative of little variability between the genotypes studied for this character.

The values for this variable ranged between 4,33 and 6 grains per pods, values that corresponded to the lines RBF14-54 and DOR-390 (TU), respectively. Only the line DOR-390 (TU) numerically surpassed the commercial cultivar CC 25-9N which presented 5,67 grains per pods.

The values obtained are in accordance with those previously reported by other authors. In this sense, in investigations for the characterization of 24 common bean lines in the 'La Compañía' Experimental Center, Carazo, Nicaragua, they obtained values of between 4 to 6 grains per pods (23).

In the cultivation of beans, developed in adverse environmental conditions, the development of the pods can be affected and consequently cause malformations and affect the grain development having as a consequence what it is known in the literature as vain pods. This can be influenced by the appearance of diseases, especially fungal and bacterial that persists in periods where high temperatures, high relative humidity and high rainfall are combined (24), conditions that coincide with the historical records of the climatic variables of the period in that this experiment was developed (Figure) (8).

In Table III, the average yield of the 15 lines and the cultivar CC 25-9N evaluated in conditions of early sowing are presented. This variable showed significant differences between the different genotypes evaluated. The values ranged between 521 and 1491 kg ha^{-1}. The MER 2222-48 line showed the best performance and statistically differed from the lines BCN 20-05, RBF 14-54, RBF 14-34, X02-33-153 and RBF 11-60 that did not exceed 750 kg ha^{-1}.

On the other hand, the commercial cultivar CC 25-9 N showed a yield of 763 kg ha^{-1}, lower than the national average, both for the state agricultural system (900 kg ha^{-1}), and for the non-state system (1100 kg ha^{-1}) as reported by the National Bureau of Statistics (25), which indicates that it is not suitable for planting in the agroclimatic conditions in which this experiment was carried out.

The lines MH 43-2, MEN 2202-16, PRO 0334-126 and MER 2222-48 showed a yield higher than 1100 kg ha^{-1}, higher than the national average for non-state agricultural systems (25), this may be determined for the adaptation capacity to the conditions of high rainfall and temperatures above the optimum required by the development of beans (20). These must be evaluated in other agricultural systems to determine the stability of their performance, as well as validate them in the different environments of the national territory.

One of the performance limitations in grain legumes is the loss of flowers of around 70 to 80 % as closed buttons and fruits that fall prematurely and only a small part reaches mature fruit. According to these results, the variability of the yield suggests that this character would be very influenced by the environment, reporting yields that vary in average from 0,3 to 3 t ha^{-1}. This would be due to the loss of flowers, which is a general feature of beans (26), which may be influenced by high temperatures, which is a prevailing condition in early plantings in Cuba.

The differences in performance are also determined by the behavior of the components that comprise it. In this case, significant differences were detected in the number of pods that is one of the main components of performance (27).

Likewise, although it was the object of study in this research, differences in yield can also be the result of different combinations of grain characteristics since biological variation between varieties has been reported in terms of morphological characteristics related to the size and weight of them. In some investigations, these characters have corroborated the variability between intra and inter bean species. Generally, the morphological characters of the seed correspond to large geographical areas, which are of great importance and provide information about the existing gene pool (28).

These variables are widely used for the characterization of bean genotypes and they are extremely important because they are related to the performance and culinary tastes (27).

CONCLUSIONS

The lines MH 43-2, MEN 2202-16, PRO 0334-126 and MER 2222-48 can be incorporated into the productive practice, especially in those farms that do not have systems for the irrigation of the crops, that have to take advantage of the humidity left by rainfall at the end of the rainy period. These lines are characterized by presenting DF between 35 and 38 days after sowing in wet soil (intermediate to late); days to the maturity of harvest between 76 and 79 DAS, less than those of the cultivar CC 25-9N that sows the farmer owner of the farm where the experiment was developed, which allows them to escape from dry periods and the attack of diseases. In addition, they expressed yields above the national average for the non-state agricultural sector (1100 kg ha^{-1}).

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