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Biomass, Grain and Nitrogen Harvest Index of Rainfed Corn with Organic and Inorganic Fertilization in a *Rhodic Luvisol* of Yucatan, Mexico

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Abstract

Corn is the staple crop in Yucatan, Mexico, mainly grown on stony soils like the Leptosols, with low productive potential, but it is also cultivated in arable areas of *rhodic Luvisols* with better potential. However, due to an imminent, continuous demand for technology, basic nutrimental studies are needed. Fertilization, associated with plant nutrition, is the most demanding technology since it is the most expensive input. Fertilization programs should pay attention to indicators related to the uptake of nutrients and their allocation into different components of the Biomass including the Grain. If fertilizers are efficiently absorbed, the profitability of the crop can increase, and environmental pollution will be reduced. This work aims to measure the Grain yield potential of corn using organic, inorganic, and biofertilization methods. It evaluated the role of Biomass in the Grain Harvest Index (**GHI**), the Nitrogen Harvest Index (**NHI**) and the amount of Nitrogen (N) needed to produce 1 t.Grain. ha^{-1}. Twelve treatments were studied with a combination of *Chemical fertilizer*, *Chicken manure* and *Biofertilizers* (*Azospirillum bacteria* + *Mycorrhiza fungus*) distributed in a completely random block design. Grain production was subjected to an Analysis of Variance (ANOVA) comparing means with a 5% Tukey test. With information from just three randomized selected treatments, the Total Biomass (**TB**) was partitioned into Stalk, Leaf, Husk and Grain to calculate the GHI and with the Nitrogen contents the NHI were assessed. Treatments were statistically different. *Chemical fertilizer* (120N-80 P_2O_5-00 K_2O) + *Chicken manure* + *Biofertilizer* was the most outstanding with 10.58

$t \cdot h^{-1}$ with a Relative Yield of 149.64% as compared to the least outstanding *Control* (00-00-00). The GHI varied from 0.49 to 0.57. The NHI ranged from 0.70 and 0.77 and between 16.33 and 18.35 $kg \cdot N \cdot ha^{-1}$ is needed to produce 1 $t \cdot Grain \cdot ha^{-1}$.

Subject Areas

Agricultural Engineering

Keywords

Nutrient Extraction, Total Biomass, Partial Biomass

1. Introduction

Soil is the medium in which plants grow to feed and clothe the world. Soil fertility is a basic need of crop production and is vital for soil to be productive. However, fertile soil is not necessarily productive soil, as other factors can limit production. Soil fertility, in modern agriculture, is part of a dynamic system, in which nutrients are extracted from the soil to be accumulated in harvested products [1].

Good soil fertility does not guarantee production, since nutrients may be in non-assimilable form. The inadequate supply of nutrients is a limiting factor for good yields, due to the fact that crops require certain quantities of nutrients according to their stage of development. The current practice of deciding on the fertilization dose is often based on general opinions with no local and specific experiences being neither effective nor economical.

The soil fertility depends on the relative rates of addition and removal of nutrients [2]. Therefore, to achieve a good fertilization program, it is necessary to know the kind and the optimal quantities of nutrients required to produce a profitable and sustainable crop in different types of soils.

In that way, fertilization should be done, based on the nutritional demand of the plant, to favor good yield expressions and to guarantee that most of the fertilizer applied is used by the crop [3].

In the state of Yucatan Mexico, corn is the main staple crop and although it is mainly cultivated on stony soils like the *Leptosols,* with low productive potential, there are important arable areas of *rhodic Luvisols* with better productive potential.

In an imminent, continuous demand for technology, basic nutrimental studies are needed to improve corn production. However, fertilization, associated with plant nutrition, is the main technological component that deserves more attention since it is the most expensive input.

To support fertilization programs it is pertinent to incorporate indicators or indexes able to measure the efficiency of fertilization as related to the uptake of nutrients by the plant and their allocation into different components of the Biomass including the Grain.

If the fertilizer applied is efficiently absorbed, the profitability of the crop can increase, and environmental pollution will be reduced.

This work aims: 1) to evaluate the effect of organic, inorganic and biofertilizers on corn Biomass production in a *rhodic Luvisol* of Yucatan, Mexico 2) To assess the *Grain Harvest Index* (***GHI***) and the *Nitrogen Harvest Index* (***NHI***) of corn crop under different fertilization formulas. 3) To assess the amount of *Nitrogen* (***N***) needed to produce one $t \cdot ha^{-1}$ of Grain.

2. Materials

The experiment was conducted in a favorable rainy season using a *rhodic Luvisol* located in the "***Uxmal***" Experimental Station of the National Institute of Forestry, Agricultural and Livestock Research of Mexico in the South of the state of Yucatán. The soil has a neutral pH (7.0), low Electrical Conductivity (EC = 0.43 mS/cm) and Medium Cation Exchange Capacity (CEC = 25 meq/100 gr, optimal concentration of both available Nitrogen as Nitric Nitrogen (NO_3-N) and Phosphorus (P) but Potassium (K) in excess.

As a phytometer, the commercial white Grain Hybrid H-565 was established in experimental units of 5 m × 4 m (20 m^2) in a projected population of 60,000 $plants \cdot ha^{-1}$.

3. Methods

3.1. Treatments and Statistical Analysis

Twelve treatments were studied (Table 1) resulting from the combination of *inorganic* (N-P_2O_5-K_2O) fertilization (80-40-00, 120-80-00 and 00-00-00) with two doses (0 and 5 $t \cdot ha^{-1}$) of *Chicken manure* (0 and 5 $t \cdot ha^{-1}$) and two doses (0% and 100%) of combined *Biofertilizers* (Azospirillum bacteria + Mycorrhizal fungus-Genus Glomus). The treatments were distributed in a Completely Randomized Block Design with two replications.

The Grain production ($t \cdot ha^{-1}$, at 13% humidity) was subjected to an analysis of variance (ANOVA) comparing means with the Tukey test at 5% in order to select the best treatments.

Table 1. Treatments related to *Chemical fertilizers* in combination with *Chicken manure* and *Biofertilizers* applied in a *rhodic Luvisol* of Yucatan Mexico.

Treatment	Chemical fertilizer N-P_2O_5-K_2O ($kg \cdot ha^{-1}$)	Chicken manure ($t \cdot ha^{-1}$)	Biofertilizer (azospirillum + mycorrhiza)
1	120-80-00	5	100
2	80-40-00	5	100
3	120-80-00	5	0
4	80-40-00	5	0
5	00-00-00	5	0

Continued

6	120-160-00	0	0
7	120-120-00	0	0
8	120-80-00	0	0
9	80-40-00	0	0
10	120-80-00	0	100
11	00-00-00	0	100
12	00-00-00 (Control)	0	0

With information on *Aboveground Biomass* (dry basis), the *Grain Harvest Index* (**GHI**) and the *Nitrogen Harvest Index* (**NHI**) were calculated for three extreme treatments: **T12** as the *Control* (00-00-00), **T6** (120-160-00) representing the *Chemical Treatment* and **T3** (120-80-00+Chicken manure) representing a *Chemical* plus an *Organic Manure Treatment* taking into account the information of the first replication only.

3.2. Grain Harvest Index (GHI)

In order to calculate the *Grain Harvest Index* (**GHI**), the aerial Total Biomass (**TB**) was partitioned in Partial Biomass (**PB**) as: Stalk, Leaves, Cob and Seed measured in kg·ha^{-1} *dry basis*. The formula for **GHI** was the next:

SHI = [***Weight of Grain/Weight of Total Biomass*** **(*Stalk* + *Leaves* + *Cob* + *Seed*)]*100**

This index measures the percentage of Grain produced as compared to the **TB**.

3.3. Nitrogen Harvest Index (NHI)

At physiological maturity, the ***NHI***, as an indicator of the magnitude of N remobilized from vegetative structures to the Grain was measured. The *Nitrogen Harvest Index* (***NHI***), considered, as well, as the percentage (%) of Nitrogen (N) extracted by the Grain, from the Total **N** accumulated in the Biomass, was calculated by taking into account.

1) The percentage (%) of **N** in each of the Biomass components (Stalk, Leaves, Cob and Seed).

2) The production (kg·ha^{-1}) of each Biomass component.

3) The content of **N** in kg ha^{-1} in each Biomass component.

So the **NHI** was calculated as follows:

NHI (%) = [(*N Content* (kg·ha^{-1}) in Seed)/(*N Content in Total Biomass* (kg·ha^{-1}))]

The **NHI** is considered an important index positively associated with Grain yield.

3.4. Nitrogen Needed to Produce 1 t·ha^{-1} of Grain

It is important to know the amount of nutrients needed to produce corn because deficiencies or excess of any mineral nutrient can affect the development of the plant. In that sense, the amount of N ($kg \cdot ha^{-1}$) to produce one ton of Grain was calculated using the next parameters.

1) N extracted for the Total Biomass ($kg \cdot ha^{-1}$)

2) Grain produced in $t\ ha^{-1}$ out of the Total Biomass

The formula used was the next:

$$N\ for\ 1\ \mathrm{t \cdot ha^{-1}} = N\ extracted\ for\ the\ Total\ Biomass\ (\mathrm{kg \cdot ha^{-1}}) / Grain\ produced\ (\mathrm{t \cdot ha^{-1}})$$

4. Results

4.1. Grain Yield and Statistical Analysis

The ANOVA (Table 2) showed highly significant differences between yield of treatments when the calculated ***p*** was of 0.009 and the maximum limit of ***p*** expected was of 0.05. Table 3 shows the Grain yields ($t \cdot ha^{-1}$) at commercial humidity of 13% of all treatments, their corresponding relative yields (%), as compared to the *Control*, and the Comparison of Means (Tukey test at 5%).

Table 2. Analysis of variance (ANOVA) of treatments related to *Chemical fertilizers* in combination with *Chicken manure* and *Biofertilizers* applied in a *rhodic Luvisol* of Yucatan Mexico.

Source of varrietion	*Square sum*	*Degree of freedom*	*Mean square*	*F*	*P* (0.05)
Treatments	28.98604583	11	2.635095076	4.585858473	0.0090
Replications	0.030104167	1	0.030104167	0.05239031	0.8231
Error	6.320745833	11	0.574613258		
Total	35.33689583	23			

The T1: (120-80-00) + *Chicken manure* + *Biofertilizer* was statistically outstanding (A). However, T1 together with other nine treatments (T2, T6, T3, T7, T9, T5, T4, T8, and T10) are statistically equals sharing the same letter A.

There are two other groups formed by sharing letters B and C with ten treatments each one. However, the *Control* (00-00-00) showed the lowest value with the letter C.

There is a clear trend of the influence that organic treatments have when mixed with biofertilizers (*Chicken manure + Biofertilizer*) and combined with inorganic fertilization. The T1 (120-80-00 + *Chicken manure* + *Biofertilizer*) obtained the highest yield with 10.58 $T \cdot ha^{-1}$ followed by T2 (80-40-00 + *Chicken manure* + *Biofertilizer*) with 10.28 $T \cdot ha^{-1}$. The inorganic T6 with the highest doses studied (120-160-00) obtained an average yield of 10.02 $t \cdot ha^{-1}$. These three treatments achieved yields of more than 40% as compared to the control.

The *Chicken manure* by itself does not contribute to any significant increase in yield; but the combination of *Chicken manure* + *Biofertilizers* creates important synergies for an important increase in production. Any way, the yields remain satisfactory with 8.68 $t \cdot ha^{-1}$ in T3 (120-80-00 + *Chicken manure*), 8.06 $t \cdot ha^{-1}$ with

T5 (00-00-00 + *Chicken manure*), 8.06 t·ha^{-1} with T4 (80-40-00 + *Chicken manure*), 7.67 t·ha^{-1} with T10 (120-80-00 + *Biofertilizer*) and 7.32 t·ha^{-1}, with biofertilizer alone T11 (00-00-00 + *Biofertilizer*).

The Biofertilizer alone is only 3% higher than the Control T12 (00-00-00), indicating little response to the application of Biofertilizers (*Azospirillum* + *Mycorrhizae*).

Looking at the three treatments (T1, T2 and T6), with the highest and similar yields, it seems that the *Chemical* treatment (T6) is the best option for corn production. From an economic point of view, the addition of *Chicken manure,* to the *Chemical* fertilizer is a non-profitable and extra expensive technological component.

Table 3. Grain yields (t·ha^{-1}) at commercial humidity of 13% and their corresponding relative yields (%) as compared to the control and the comparison of means by Tukey test ($p = 0.05$).

Treatment	T·ha^{-1}			*Relative yields* (%)	*Comparison of means* (*Tukey* 5%)
	I	*II*	*Avarage*		
*T*1. (120-80-00) + *Chicken manure* + *Biofertilizer*	10.58	10.58	10.58	149.64	*A*
*T*2. (80-40-00) + *Chicken manure* + *Biofertilizer*	10.29	10.27	10.28	145.40	*AB*
*T*6. (120-160-00)	10.21	9.82	10.02	141.72	*ABC*
*T*3. (120-80-00) + *Chicken manure*	8.26	9.09	8.68	122.77	*ABC*
*T*7. (120-120-00)	9.24	7.99	8.62	121.92	*ABC*
*T*9. (80-40-00)	8.48	8.32	8.40	118.81	*ABC*
*T*5. (00-00-00) + *Chicken manure*	8.05	8.07	8.06	114.00	*ABC*
*T*4. (80-40-00) + *Chicken manure*	9.14	6.98	8.06	114.00	*ABC*
*T*8. (120-80-00)	7.46	8.65	8.06	114.00	*ABC*
*T*10. (120-80-00) + *Biofertilizer*	7.49	7.86	7.67	108.48	*ABC*
*T*11. (00-00-00) + *Biofertilizer.*	7.09	7.55	7.32	103.53	*BC*
*T*12. (00-00-00) *Control*	6.09	8.05	7.07	100.00	*C*

4.2. The *Chemical* and the *Chicken Manure* vs. Biomass Production

Figure 1 shows the **TB** production (kg·ha^{-1}), dry basis, of three specific treatments. The *Control* T12 (00-00-00) obtained the lowest **TB** production with 10,800 kg·ha^{-1} followed by T6 (120-160-00) with 12,190 kg·ha^{-1} and T3 (120-80-00 + *Chicken manure*) with 14,798 kg·ha^{-1}. There was a **TB** reduction of 27% in T12 as compared to T3.

On the other hand, the production of Partial Biomass (**PB**) (Husk, Leave and Stalk) in the *Control* T12 (00-00-00) was 5500 kg·ha^{-1} whilst for the Inorganic fertilizer T6 (120-160-00) it was 5140 kg·ha^{-1} and for the T3 (120-80-00 + *Chicken manure*) the **PB** was the higher with 7608 kg·ha^{-1}. The Grain production (dry basis) were 5300, 7050 and 7190 kg·ha^{-1} for T12, T6 and T3 respectively.

Although the **PB** was higher in the most complete T3 (*Chemical fertilizer and Chicken manure*) the Grain yield (7190 kg·ha−1) was similar to that of the Chemical treatment T6 (7160 kg·ha^{-1}). It seems that in T3 there was a *Luxury*

Consumption when plants were over-fertilized and the Biomass concentrated more in the Stalk than in the Grain as shown in Figure 1.

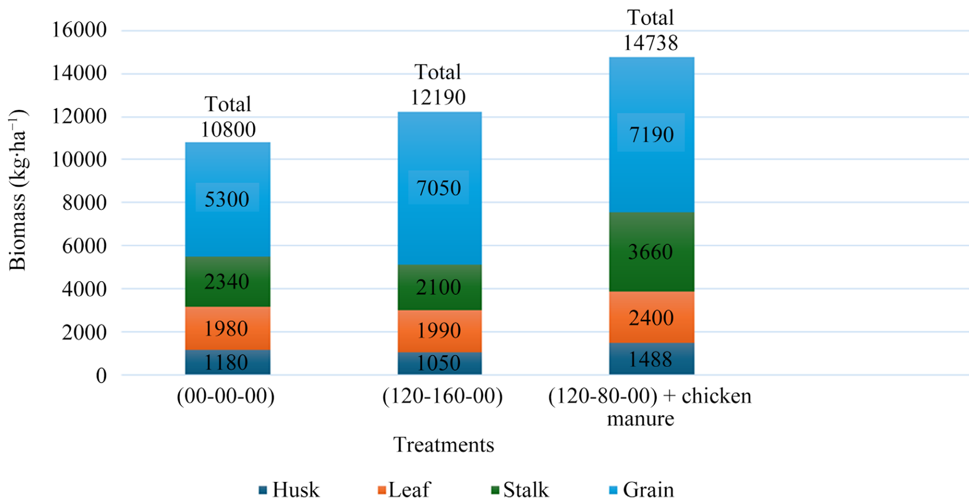

Figure 1. Production of dry base Biomass (Kg·ha^{-1}) partitioned in Husk, Leaf, Stalk and Grain with different fertilization treatments in a *rhodic Luvisol* of Yucatan Mexico. Uxmal-INIFAP Experimental Station.

4.3. Harvest Indexes (GHI-NHI) and Kilograms of N to Produce 1 t·Grain·ha^{-1}

The values of Grain Harvest Index (**GHI**), Nitrogen Harvest Index (**NHI**) and kilograms of **N** needed to produce 1 t·ha^{-1} of Grain are shown in Tables 4-6 for T12, T6 and T3 respectively.

The **GHI** referred to as 0.49 (49%), 0.57 (57%) and 0.48 (48%) for T12, T6 and T3 respectively are in the range (0.50 - 0.52) reported by Cimpiatti, *et al.* (2010) [4]. This means that, regardless of the treatments, between 48 and 57% of the **TB** is concentrated in the Grain.

To calculate the **NHI**, both the **N** content in each component of the **TB** and the kilograms per hectare produced were used. By instance, the **N** contents in Grain were similar in all three treatments: 1.34%, 1.27% and 1.30% for T12, T6 and T3 respectively. That was not the case for **N** in Leaves where **N** was lower in the *Control* T12 (0.43%) vs. 0.68 and 0.80% for T6 (*Chemical fertilizer*) and T3 (*Chemical fertilizer and Chicken manure*) respectively.

It was found that the Grain in T12, T6 and T3 accumulates 71.02, 89.53 and 93.47 Kg of N·ha^{-1} respectively; representing 74% of the total **N** extracted by the **TB** (95.02 Kg of N·ha^{-1}) for T12, 77% for T6 (115.18 Kg of N·ha^{-1}) and 70% for T3 (132.04 Kg of N·ha^{-1}).

In that way, the **NHI** of 0.74, 0.77 and 0.70 for T12, T6 and T3 are in accordance with the findings of Hutsh and Shuber, (2023) [5] who reported an average **NHI** of 0.75.

On the other hand, in order to produce 1 t·ha^{-1} of Grain, it is needed 18.00, 16.33 and 18.35 Kg·N·ha^{-1} extracted by the **TB** for T12, T6 and T3 respectively

(**Tables 4-6**). This is in accordance with different authors who suggested values of 23.1 [6] and 15.0 kg·N [7] for each ton of Grain to be produced.

Table 4. Biomass Production (kg·ha^{-1} dry basis), Grain Harvet Index (***GHI***), Nitrogen Harvest Index (***NHI***) and Kilograms of N to produce 1 t·Grain·ha^{-1} in the *Control* (00-00-00) **T12**. Uxmal-INIFAP Experimental Station at Yucatan Mexico.

Treatment	Parameters	Stalk	Leaf	Husk	Grain	Partial Biomass	Total Biomass
T12 (00-00-00)	Kg·ha^{-1}	2340	1980	1180	5300	5500	10,800
	Harvest Index (HI) per component	0.22	0.18	0.11	0.49		
	N (%) in each Biomass component	0.44	0.43	0.44	1.34		
	Kg·N·ha^{-1} exported to each component.	10.29	8.51	5.19	71.02		95.022
	Nitrogen Harvest Index (NHI)	0.10	0.089	0.054	0.74		
	kg·N·ha^{-1} to produce 1 t·Grain·ha^{-1}				18.00		

Table 5. Biomass Production (kg·ha^{-1} dry basis), Grain Harvet Index (***GHI***), Nitrogen Harvest Index (***NHI***) and Kilograms of N to produce 1 t·Grain·ha^{-1} in the *Chemical fertilizer* **T6** (120-160-00). Uxmal-INIFAP Experimental Station at Yucatan Mexico.

Treatment	Parameters	Stalk	Leaf	Husk	Grain	Partial Biomass	Total Biomass
T6 (120-160-00)	Kg·ha^{-1}	2100	1990	1150	7050	5140	12,190
	Harvest Index (HI) per component	0.17	0.16	0.09	0.57		
	N (%) in each Biomass component	0.38	0.68	0.36	1.27		
	Kg·N·ha^{-1} exported to each component.	7.98	13.53	4.14	89.53		115.18
	Nitrogen Harvest Index (NHI)	0.069	0.11	0.036	0.77		
	kg·N·ha^{-1} to produce 1 t·Grain·ha^{-1}				16.33		

Table 6. Biomass Production (kg·ha^{-1} dry basis), Grain Harvet Index (GHI), Nitrogen Harvest Index (NHI) and Kilograms of N to produce 1 t·grain·ha^{-1} in a Chemical and Organic Fertilizer T3 (120-160-00 + Chicken manure). Uxmal-INIFAP Experimental Station at Yucatan Mexico.

Treatment	Parameters	Stalk	Leaf	Husk	Grain	Partial Biomass	Total Biomass
T3 (120-80-00 + Chicken manure)	Kg·ha^{-1}	3660	2460	1488	7190	7608	14,798
	Harvest Index (HI) per component	0.24	0.16	0.10	0.48		
	N (%) in each Biomass component	0.37	0.80	0.36	1.30		
	Kg·N·ha^{-1} exported to each component.	13.54	19.68	5.35	93.47		132.04
	Nitrogen Harvest Index (NHI)	0.10	0.15	0.04	0.70		
	kg·N·ha^{-1} to produce 1 t·Grain·ha^{-1}				18.35		

5. Discussion

In the first part of this work, related to Grain yields (**Table 3**) it was observed a synergic effect of *Chicken manure* and the *Biofertilizer*. However, *Chicken manure* alone was able to enhance yields (T5) but Biofertilizer was not (T11). Biofertilizers did not have any effect on yields even when applied with Chemical fertilizers (T10). Biofertilizers were activated only when *Chemical fertilizers* were added with the *Chicken manure*.

It seems that the *Mycorrhizal* fungi, in the biofertilizer, found enough nutrients, coming from both the *Chicken manure* and the C*hemical fertilizer.* **N** was transported into the roots and plant through their hyphae when in contact with a fertile soil.

Sorensen, *et al*., (2009) [8] suggests that the increase in the *Mycorrhizal* colonization are due to the presence of Organic Matter as a source of energy for soil organisms. According to Uriel-Figueroa, *et al*. (2015) [9] the **N** in *Chicken manure* is two times higher (2.6% - 4.65%) than that of the *Bovine Manure* (0.91% - 2.44%).

On the other hand, it is possible that the excesses of Nitrogen, coming mainly from *Chicken manure*, are inhibiting the activity of the *Azospirillum* bacteria. The biological N fixation process decreases when soils have high N content as mentioned by Steenhoudt and Vanderleyden, (2000) [10]. These authors mention that the *Nitrogen Fixation Structural Genes* (***nif***) are highly conserved among all nitrogen-fixing bacteria and the *Transcriptional Activator* ***NifA*** is required for **N** fixation. In *Azospirillum brasilense* and *H. seropedicae*, ***NifA*** is inactive when N is in excess.

On the othe hand, in the second part of the research, it was found a highest 0.8% of **N** in leaves when *Chichen manure* was combined with the *Chemical fertilizer* (**T3** = 120-80-00 + *Chicken manure*), whilst in the *Control* (**T12**) and the *Chemical treatment* (**T6**) the **N** reduced to 0.43% and 0.68% respectively (**Tables 4-6**). The Partial Biomass (**PB**) of T3 (7608 kg·ha^{-1}), which is the sum of all components except Grain, was higher than both the *Control* (5500 kg·ha^{-1}) and the *Chemical* treatment (5140 kg·ha^{-1}).

However, eventhough **T3** showed higher **TB**, **PB** and **N** content in leaves than those of the *Chemical* **T6**, both treatments had practically the same Grain Yields (7190 vs. 7050 kg·Grain·ha^{-1}). This could be related to the **N** L*uxury Consumption* (**LC**) when a soil is overfertilized. In this sense, yield can be decreased by excesive **N** as suggested by Cope and Rose, (1973) [11].

The **LC** occurs when the crop absorbs nutrients without a corresponding increase in yield involving also an extra cost of fertilization. In our case, it seems that **N** in **T3** was absorbed but no assimilated to enhance kernels production.

It is suggested that in maize, and other crops, **N** can be remobilized (before silking), to ears to supply kernels formation [12] [13]. Yields are well related to an increase in the dry matter and the consequent accumulation of nutrients [14]. The N remobilization can be disrupted under stress conditions [15].

On the other hand, the N extracted for the **TB** to produce 1 t·ha^{-1} of Grain was 18.0, 16.3 and 18.3 kg·N·ha^{-1} for T12, T6 and T3 respectively. This findings were not far away from those reported by different authors [6] [7].

On **Table 7** below, there is a summary of the **GHI**, **NHI** and the kilograms of **N** needed to produce 1 ton of corn, product of this work, as compared to the literatue.

Table 7. Summary of principal finding on *Grain Harvet Index* (*GHI*), *Nitrogen Harvest Index* (*NHI*) and Kilograms of N to produce 1 ton·Grain·ha^{-1} of three extreme different treatmens as compared to the literature. Uxmal-INIFAP Experimental Station at Yucatan Mexico.

Treatments	GHI (Index)	NHI (Index)	N for 1 t·ha^{-1} (kg·ha^{-1})
T12 (*Control*)	0.49	0.74	18.00
T6 (120-160-0)	0.57	0.77	16.33
T3 (120-80-00 + *Chicken manure*)	0.48	0.70	18.35
References	**0.50 - 0.52** [4]	0.75 [5]	23.10 [6] 15.00 [7]

6. Conclusions

Nowadays, fertilization related to plant nutrition is one of the main issues to be investigated, from an agronomic point of view, since it is the most expensive input for corn and other crops. Fertilization research programs should pay attention to select *indicators* or indexes related to the ***uptake*** of nutrients and their allocation into different components of the Biomass, including the Grain.

In that way, farmers can be more efficient when applying fertilizers in the appropriate doses and at the correct time, reducing economic losses. And avoid environmental pollution.

This work aimed to discover new agronomic parameters, for corn **Hybrid H-565**, such as: the Grain Harvest Index (**GHI**), the Nitrogen Harvest Index (**NHI**) and the amount of Nitrogen (**N**) needed to produce one t·t·ha^{-1} of Grain. To do so, Total and Partial Biomass (**TB** and **PB**), as well as **N** (%) in each Biomass component was assessed.

After studying twelve treatments combined with *Chemical fertilizer*, C*hicken manure* and *Biofertilizers* (*Azospirillum brasilense bacteria* + *Mycorrhiza fungus*), the Grain production was subjected to an Analysis of Variance (ANOVA) comparing means with a 5% Tukey test.

Thie main conclusions were the next.

1) Significant statistical differences were found between treatments.

2) Corn production, is enhanced by applying *Inorganic fertilizers*, alone or combined with *Chicken manure* and/or *Biofertilizers*, but just three treatments (**T1**, **T2** and **T6**) resulted with better relative yields (%) as compared to the *Control* (**T12**).

3) The T1 (120-80-00 + *Chicken manure* + *Biofertilizer* was the most outstanding with 10.58 t·ha^{-1} followed by **T2** (80-40-00 + *Chicken manure* + *Biofertilizer*) and **T6** (120-160-00) with 10.28 and 10.02 t.ha^{-1} respectively.

4) In order to reduce costs, **T6** is a better option than **T1** and **T2** since no additional *Chicken manure* nor *Biofertilizers*, as an extra cost, are needed, maintaining practically the same yields.

5) The **GHI** varied from 0.49 to 0.63 indicating that between 49% and 63% of the **TB** belongs to *Grain*. The **T6** had the highest **GHI** with 0.57.

6) The **NHI** ranged between 0.63 and 0.81, suggesting that between 63% and 81% of the total N in the the **TB** is extracted by the *Grain*. The **T6,** again showed the higher **NHI** with 0.77.

7) To produce one ton *Grain* per hectare, the **TB** extracted between 16.33 and 18.35 $kg \cdot N \cdot ha^{-1}$. The **T6** shows the lowest value with 16.33 vs. **T12** (18.00) and **T3** (18.35). This means that the N in T6 was used more efficiently to produce *Grain*.

8) Although the combination of *Chemical* fertilizer with *Chicken manure* induced higher Biomass production, there was not a substantial increase in Grain yield. It seems that a *Luxury Consumption* of N can explain it.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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