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Research Article

Evaluation of Alley-cropping Agroforestry System and Conventional System of Agriculture on the Productivity of Cabbage (*Brassica oleracea* L.) in Dschang, West Region of Cameroon

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Abstract

Cabbage is one of the main vegetable crops grown in Cameroon. However, production is limited by rising prices and the scarcity of chemical fertilisers on the market. The rise in cost of fertilizers leaves some farmers reluctant to use fertilisers and as a result leads to lower yields, hence, low crop profitability. The aim of this study was to compare the two systems of agriculture; agroforestry system with the conventional system on the growth of cabbage (*Brassica oleracea* L.). Research plots were established on the campus of the University of Dschang, in the West Region of Cameroon. The comparisons were made on the basis of productivity, pest abundance and economic profitability. Data on yield and pest susceptibility variables were collected during the field trials. It was realised that the slug (*Deroceras reticulatum*) population was higher in the agroforestry system (4.62±2.41 slugs) than in the conventional system (1.03±0.55 slugs). The aphid population (*Brevicoryne brassicae*) was higher in the conventional cropping system (25.31±38.94 aphids) compared with the alley-cropping agroforestry system (0.71±0.62 aphids). Productivity variables showed that cabbage yield did not vary between the two production methods. It was 66.08 t/ha and 66.76 t/ha respectively for the agroforestry system and the conventional system. The economic analysis showed that the agroforestry system was more profitable than the conventional system. Thus, growing cabbage in an agroforestry system is an ecological and profitable strategy for agriculture that is more resilient to climatic variations.

Keywords

Cabbage, Production Mode, Economic Profitability, Alley-cropping Agroforestry System, Conventional Cropping System

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1. Introduction

Cabbage (*Brassica oleracea*) is an edible plant in the Brassicaceae, native to south-western Europe. The Brassicaceae is a large and very diverse group of crops cultivated worldwide [8]. Nutritionally, cabbage is rich in vitamins, vegetable fibre, trace elements and minerals. Cabbage is high in calories (36, 5 Cal /100g) and contains carbohydrates, fibres and high level of vitamins such as vitamins E, K, B2 and B3. Coupled to these, they contain important food nutrients like proteins, calcium, iron, iodine, copper, chlorine, magnesium, manganese, phosphorus, potassium, sodium and zinc [2]. The phenols, glucosinolates and vitamins present in cabbage have anti-carcinogenic, antioxidant, anti-inflammatory and cardio-protective effects [1, 10, 14]. They are equally rich in flavonoid and phenolic acids [9].

Cabbage is a vegetable crop known throughout the world for its ability to withstand a wide range of climatic and soil conditions [8]. Cabbage is grown on around 3 million ha in 124 countries, as follows: 2 million ha in Asia, 1/2 million ha in Europe, 180,000 ha in the Americas and the equivalent of 100,000 ha in Africa [16]. According to the Food and Agriculture Organization of the United Nations [7], global cabbage production is 73.8 million tonnes per hectare. In Africa, at least 40,000 ha are grown in countries such as Kenya, Uganda and Tanzania; 10,000 ha in Malawi, Zambia and Zimbabwe; 4,000 ha in Ethiopia and 3,000 ha in Cameroon [16]. In Cameroon, it is mostly grown in the western highlands (West and North-West Regions) where the fairly cold climate is favourable [3]. Cabbage yield in Cameroon is estimated at 25 tonnes per hectare [4].

For decades, the risks of soil degradation have been a major concern for environmentalists [18]. Market gardening is one of the most productive agricultural systems in Africa [5]. It plays an important role in human nutrition and makes a significant contribution to family income, but production is limited by the management of the farming system used (soil degradation and environmental pollution) [12]. As a result, combining crops with woody legumes in agricultural exploits makes it possible to restore fertility and land use sustainably [13, 17]. In such a context, agroforestry is an appropriate solution for restoring soil fertility and soil sustainability, and even contribute to food self-sufficiency.

There is growing consensus among scientists on the need to increase food production to meet the demands of the ever-increasing global population. However, this required increase in food production presents an unprecedented challenge to researchers since it must happen within the context of increasing environmental degradation and climate change concerns. Agroforestry systems are receiving much attention in recent times because they are at the intersection of agricultural productivity improvement, environmental protection and climate change mitigation through the unique ability to combine food crops and trees within the same space. This study therefore seeks to investigate the feasibility of adopting the agroforestry system of farming by assessing the effect of two farming systems (agroforestry and conventional systems) on the pest abundance and yield of cabbage in Dschang, West region of Cameroon.

2. Materials and Methods

2.1. Study Area

This research was carried out in Dschang in the Menoua Division of the West Region of Cameroon; which is found in the Western High Plateaux agro- ecological zone from the period of August to December 2022. Dschang is located at latitude 05°26.617' North and longitude 10°04.184' East. Dschang is characterised by an annual rainfall that varies from 1800 and 2000 mm annually, with annual temperatures between 13.02 and 26.73 ℃ and relative humidity of 60 % [19]. The field experiment was conducted at the research farm of the University of Dschang from August to December 2022.

2.2. Experimental Design

This study made use of a complete randomized design made up of two treatments (agroforestry and conventional farming systems) and a control group which were all replicated 3 times. The agroforestry system was an alley-cropping system in which the plots were laid in the alleys of 20 trees of *Gliricidia sepium* and the soil was amended using the fresh biomass of *Gliricidia sepium*, deposited on the ground in the plots as green manure at the rate of 8.5 t/ha, 30 days before transplant. In the conventional system, inorganic fertilizer (NPK) 80-40-60 was applied 3 weeks after transplanting, at the rate of 5g per plant. This compound fertilizer was obtained following a mixture of three simple fertilizers which are: urea (46% N), DAP (Di-ammonia phosphate 18-46-0) and potassium chloride (KCl, 60% K2O), i.e. a quantity of approximately 1.05 kg for the entire conventional plot and 194 kg/ha. The control group did not receive any treatment.

2.3. Soil Collection

Soil samples were collected from the alley-cropping agroforestry system and from the conventional system and analysed for physico-chemical parameters. The analyses were carried out independently for the two systems.

2.4. Nursery Establishment and Management

The nursery space was cleared, demarcated and ploughed. The ploughed space (15m long and 1m wide) was leveled and the soil was amended by spreading poultry manure on it. Sowing lines of 5cm depth and 25cm apart were made, the seeds were spread along the lines and covered with a thin layer of soil. To avoid direct contact between the sown seeds and the water during watering, mulching was done using dead grass. After seed germination (6 days after sowing), the mulch was removed and the nursery was covered with mosquito nets to keep away birds. Weeding was carried out 8 days after germination while the healthy seedlings were transplanted 2 weeks after weeding, when the plants were at the 4-5 leaves stage.

2.5. Land Preparation and Transplanting

Land preparation began with clearing and demarcation of the experimental field following the experimental design. The field was ploughed using a hoe to a depth estimated at 15cm, sowing lines were made using a string and stakes and holes of 20cm in width and depth were made using a hoe. The spacings between the holes were 50 × 50 cm, for a plant density of 40,000 plants/ha. The tree species *Gliricidia sepium* was pruned in the alley agroforestry system and the biomass of this species was deposited on the ground. One week after pruning, the different plots received an amendment of chicken droppings at a rate of 3t/ha for 78g per hole. Healthy seedlings were removed from the nursery and transplanted in the prepared holes.

2.6. Crop Management

Insect pests were controlled using the insecticide Cypercot (Cypermethrin 100 E.C.) applied 14 days after transplanting at the rate of 20 ml per 15L knapsack sprayer. Weeds were eliminated by manual weeding with the aid of a hoe. Weeding was done twice (3 weeks after transplanting and 30 days after the first weeding) during the experimental period.

2.7. Data Collection

Crop yield was assessed by collecting data on cabbage root and head mass. This was done by separating the head from the root and weighing them separately on an electronic balance. Data on pests were collected for slug, spider and aphid population and data collection involved observing the upper, lower faces and the center of the plants and manual counting was done and recorded in the data collection sheet.

2.8. Data Analysis

The data collected were entered into Microsoft Excel version 2016 software. After importing these data into the R software version 4.0.3, an independent samples t test was conducted between the different treatments at the 5% significance level.

3. Results

3.1. Soil

In the alley-cropping agroforestry system, the soil analysis results indicate a low level of acidity with pH close to neutrality (pH water=6.2), a high organic matter content (6 %), an average total nitrogen content of 0.30 %, as well as percentage of exchangeable bases such as calcium (16 meq/100 g), magnesium (3.60 meq/100g), potassium (0.64 meq/100 g), sodium (0.41 meq/100g) and an average content of assimilable phosphorus (56.41 mg/kg). In the conventional system, the soil analysis results indicate a moderately acidic pH (pH water=5.8), an organic matter content of 4.20%, an average total nitrogen content of 0.21%, and exchangeable bases such as calcium (10.80 meq/100 g), magnesium (1.60 meq/100 g), potassium (0.56 meq/100 g), sodium (0.41 meq/100 g) and assimilable phosphorus content of 57.72mg/kg.

3.2. Yield

The agroforestry system resulted in a yield of 66.09±1.28 t/ha, and this yield varied less than the yields of the other systems. The statistical range (max - min) of the cabbage yield is 2, 35 t/ha in the agroforestry system, whereas the range of the yield in the conventional system was 12,86 t/ha and that of the control was 29,45 t/ha.

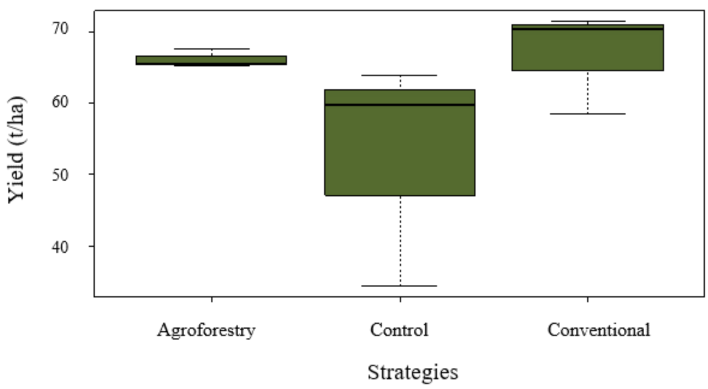

Figure 1. *The yield performance of cabbage across the treatments.*

The yield shows that there is no significant difference between the cabbage plants in the alley-cropping agroforestry system, the conventional system and the control plot (no fertilisation). The average cabbage yield showed no significant difference (P>0.05) between the alley-cropping agroforestry system (66.08±1.28 t/ha), the conventional system (66.76±7.5 t/ha) and the control (52.71±15.95 t/ha).

Table 1. Comparison of the yields of cabbage for different cropping systems.

Variable	Contrast	Difference	Degree of freedom	T ratio	P-value
Yield (t/ha)	AS vs CS	-2.59±4.61	60	-0.561	0.8414^{ns}
	AS vs CT	11.46±5.26	60	2.181	0.0828^{ns}
	CS vs CT	14.05±5.26	60	2.672	0.0258*

AS: agroforestry system; CS: conventional system; CT: control.

3.3. Pests

Slugs

The results showed that the abundance of slugs as a function of days after transplanting varies in the different production systems. In the alley-cropping agroforestry system, the slug population increases from the 30th to the 44th day after transplanting then decreases from the 44th to the 58th day after transplanting (Figure 2).

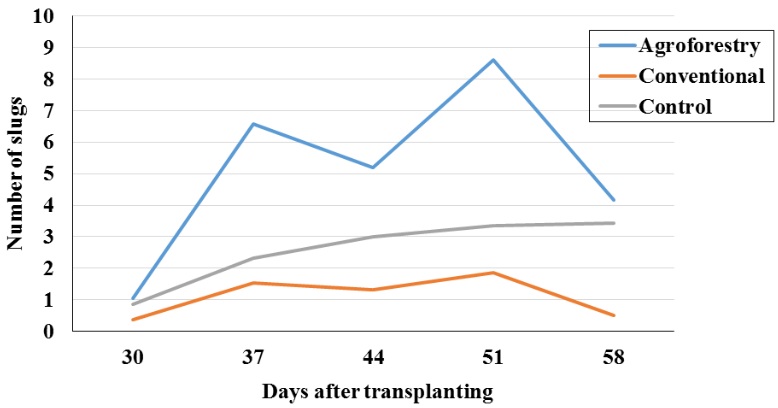

Figure 2. Slug population trends across the different production systems.

At 30th days after transplanting, no significant difference (P>0.05) was observed between the agroforestry system and conventional system cropping strategies. However, at the 44th and 58th days, the difference between agroforestry system and conventional system was 3.87±0.957 and 3.666±0.819 respectively. This difference was highly significant and shows that agroforestry system cabbages had a higher number of slugs (P <0.05) than conventional system cabbages.

At 30th, 44th and 58th DAT no major difference (P>0.05) was observed between the number of slugs in agroforestry system and control.

At 30th days the difference between conventional system and control was -1.558±0.472. This difference was significant (P<0.05) and showed that cabbages under the control group had a significantly higher number of slugs than conventional system cabbages. Similarly, at 44th and 58th DAT, the difference between the number of slugs in the conventional system and the number of slugs in the control was significant (P<0.05).

Table 2. Comparison of slug numbers for different cropping strategies.

DAT	Contrast	Difference	Degree of freedom	T ratio	P
30	AS vs CS	0,667±0,414	60	1,610	0,2495 ns
	AS vs CT	-0,892±0,472	60	-1,888	0,1509ns
	CS vs CT	-1,558±0,472	60	-3,300	0,0046**
44	AS vs CS	3,875±0,957	60	4,050	0,0004***
	AS vs CT	-0,925±1,091	60	-0,848	0,6749 ns
	CS vs CT	-4,800±1,091	60	-4,400	0,0001***
58	AS vs CS	3,6667±0,819	60	4,476	0,0001***
	AS vs CT	0,0333±0,934	60	0,036	0,9993 ns
	CS vs CT	-3,633±0,934	60	-3,890	0,0007***

Significance levels: ***: 0.001 and NS: Not significant

3.4. Aphids

The number of aphids increased at 58th days after transplanting in the conventional system and in the control plot. However, there were no aphids in the alley-cropping agroforestry system (Figure 3).

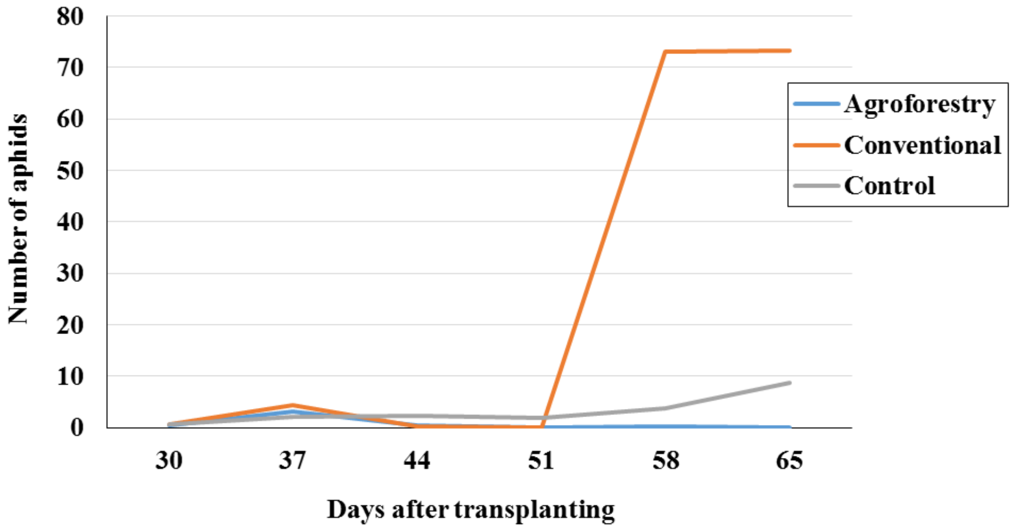

Figure 3. Aphid population trends by farming system.

At 30, 44 and 58 DAT no significant difference (P>0.05) was observed between aphid numbers in AS and CS. At 30 DAT, the difference between agroforestry system and control was not significant (P>0.05). However, at 44 DAT, the difference between the number of aphids in agroforestry system and the number of aphids in control was -4.208±0.636. This difference was significant (P<0.05) and shows that the number of aphids from control was higher than the number of aphids from AS. At 58 DAT, the difference between agroforestry system and control was not significant (P>0.05).

At 30 DAT, the difference between conventional system and control was not significant (P>0.05). However, at 44 DAT, the difference between the number of aphids in the conventional system and the number of aphids in the control was -4.417±0.636. This difference was significant (P<0.05) and it showed that the number of aphids in the control was higher than the number of aphids in the conventional system. At 58th DAT, the difference between conventional system and control was not significant (P>0.05).

Table 3. *Comparison of aphid numbers for the different cropping systems.*

DAT	Contrast	Difference	Degree of freedom	T ratio	P
30	AS vs CS	-0,167 ±0,368	60	-0,453	0,8934 ns
	AS vs CT	-0,292 ±0,420	60	-0,695	0,7674ns
	CS vs CT	-0,125 ±0,420	60	-0,298	0,9523 ns
44	AS vs CS	0,208 ±0,558	60	0,374	0,9260 ns
	AS vs CT	-4,208 ±0,636	60	-6,620	0,0001***
	CS vs CT	-4,417 ±0,636	60	-6,948	0,0001***
58	AS vs CS	-72,9 ±45,8	60	1,593	0,2564 ns
	AS vs CT	-20,5 ±52,2	60	-0,393	0,9186 ns
	CS vs CT	52,4 ±52,2	60	1,005	0,5769 ns

Significance levels: ***: 0.001 and ns: Not significant

3.5. Economic Profitability

Table 4 shows the economic profitability of the treatments per hectare. These results showed that the alley-cropping agroforestry system, the conventional system and the control system (without fertilisation) had profits of 2,363,013 FCFA/ha, 2,648,484.5 FCFA/ha and 1,053,189.5FCFA/ha respectively. These three production methods were therefore profitable. However, the alley-cropping agroforestry system had a higher economic return (2.69) than the conventional system (2.51) and the control (1.31).

Table 4. *Economic profitability of production methods.*

Matrix	AS	CS	CT
Yield (t/ha)	66, 08	66,76	52,71
Seeds (FCFA)	160000	160000	160000
Organic fertilisers (FCFA)	262500	262500	262500
Chemical fertilisers (Uree-DAP-KCL) (FCFA)	/	132500	/
Plant protection product - Insecticide	3000	3000	3000
Installation labour (FCFA)			
- Clearing	50000	50000	50000
- Ridging	30000	30000	30000
- Mowing biomass spreading	30000	/	/
- Application of organic fertiliser	30000	30000	30000
- Sowing	30000	30000	30000
Labour chemical fertiliser application (FCFA)	/	30000	/
Sarclo-buttage labour (FCFA)	60000	60000	60000
Transport of chemical fertiliser (FCFA)	/	15000	/
Transport of organic fertiliser (FCFA)	15000	15000	15000
Harvesting and packaging labour (FCFA)	30000	30000	30000
Harvest transport (FCFA)	97215	111105	55555

Matrix	AS	CS	CT
PC (FCFA)	797715	959105	726055
II (FCFA)	79771,5	95910,5	72605,5
CP (FCFA)	877486,5	1055015,5	798660,5
CR (FCFA)	3240500	3703500	1851850
Profit (FCFA)	2363013,5	2648484,5	1053189,5
Profitability % (RT)	2,69	2,51	1,31
VCR	3,69	3,51	2,31

PC: Production Cost; CP: Cost Price; CR: Cost of return; II: Interest on investment;
VCR: Value to cost ratio

4. Discussion

The results of the statistical analysis showed that the cabbages in the conventional system (CS) and the control plot (no fertilisation) had fewer slugs than those in the alley-cropping agroforestry system (AS). This is because the high humidity created by the species *Gliricidia sepium* in the agroforestry system encourages the rapid proliferation of slugs. This is in agreement with Seighieri and Harmand [15] who showed that the high moisture content created by the trees in an alley agroforestry system is a factor favouring the presence of slugs. In contrast, the conventional system and the control plot had fewer slugs because the exposed nature of the plots prevents the accumulation of moisture.

Cabbages in the alley-cropping agroforestry system were less susceptible to aphids than the plants in the conventional system and the control plot. This can be explained by the fact that *Gliricidia sepium* in association with cabbage had a repellent effect on aphids, which resulted in a low percentage of aphids in the alley-cropping agroforestry system compared to the conventional system and the control plot. This is in agreement with Mathew *et al*. [11] who mention that *Gliricidia sepium* is known as a plant with insecticidal properties.

Statistical analysis showed that cabbage yield (t/ha) did not vary significantly (P > 5%) between the agroforestry system (66.08 t/ha), the conventional system (66.76 t/ha) and the control plot (52.71 t/ha). These results are not far from those of Kang *et al*. [20] who, in seven years of experimentation, obtained similar yields in the agroforestry system and in the conventional cultivation system with mineral fertiliser. However, they contradict the results obtained by Mathew *et al.* [11], who showed that spreading *Gliricidia sepium* prunings as a mulch significantly improved maize yields in 106 cropping systems.

Economic profitability was higher in the alley-cropping agroforestry system than in the conventional system and the control. This can be explained by the fact that the costs associated with the use of chemical fertilisers are non-existent in alley-cropping agroforestry systems. According to the FAO [6], a cropping system is profitable when its value yield is greater than or equal to 2 (VCR > *2).* In view of the results obtained, the alley-cropping agroforestry system is more economically profitable than the conventional system and the control. Environmental wise, as stipulated by Ayoub *et al.* [1], the unreasonable use of fertilizers is detrimental to the environment, and in particular to water sources, as well as to human health through the quality of the food consumed.

5. Conclusion

The aim of this study was to propose a cropping system likely to improve cabbage productivity in the West Cameroon region, in an agroecological context. The results showed that cabbage yields did not vary significantly in the conventional system compared with the alley-cropping agroforestry system and the control. Also, the alley-cropping agroforestry system had an unfavourable effect on the aphid population compared with the conventional system and the control. The number of aphids in the conventional system was higher than the number of aphids in the alley-cropping agroforestry system and the control. On the other hand, slug numbers were higher in the alley-cropping agroforestry system than in the conventional system and the control. An analysis of economic profitability showed that the alley-cropping agroforestry system was more profitable than the conventional system and the control plot. Future research should explore the long-term impacts of alley-cropping on soil health and nutrient cycling, particularly with various leguminous species, as well as investigate diverse tree-crop combinations to enhance biodiversity and natural pest control. Economic analyses across different staple and cash crops could further establish the profitability of alley-cropping, while studies on climate resilience would assess agroforestry's role in improving soil moisture retention and yield stability under extreme weather. Additionally, examining the carbon sequestration potential of alley-cropping systems could reveal valuable insights for climate change mitigation. These areas collectively offer promising directions to enhance sustainable and resilient agricultural practices.

Abbreviations

FCFA	Franc of Financial Cooperation in Africa
FAO	Food and Agriculture Organisation
VCR	Value to Cost Ratio
II	Interest on Investment
CP	Cost Price
PC	Production Cost
AS	Agroforestry System
CS	Conventional System
CT	Control

Author Contributions

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Beyegue Djonko Honore: Conceptualization, Formal Analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing

Yannick Afanga Afanga: Data curation, Formal Analysis, Investigation, Methodology, Resources, Writing – original draft, Writing – review & editing

Nyayi Tonda Hortense Inès: Data curation, Investigation, Methodology, Writing – review & editing

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Conflicts of Interest

The authors declare no conflicts of interest.

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Research Fields

Etanke Sylvie Essomo: Horticulture, Agroecology, Crop production, Crop protection, Plant pathology, Plant physiology

Besem Doris Arrey: Plant pathology, Crop protection, Crop production, Ethnobotany, Ethnomedicin

Beyegue Djonko Honore: Agricultural sciences, Agronomy, Plant Genetics and Breeding, Biostatistics, Crop protection

Yannick Afanga Afanga: Plant Biotechnology, Plant Breeding, Plant Genetics, Plant pathology, Plant physiology

Nyayi Tonda Hortense Inès: Horticulture, Crop production, Crop protection, Agroecology, Agronomy

Egoumé Guissana Antoine: Biostatistics, Agroecology, Plant Genetic Improvement, Biotechnology, Agronomy