PATH COEFFICIENT ANALYSIS IN SUGARCANE

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MASTER OF SCIENCE IN AGRICULTURE
(PLANT BREEDING)

JULY, 2000

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The thesis attached hereto, entitled "PATH COEFFICIENT ANALYSIS IN SUGARCANE", in partial fulfillment of the requirements for the degree of Master of Science in Agriculture, is here by accepted.

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PATH COEFFICIENT ANALYSIS IN SUGARCANE

ABSTRACT

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This study was conducted to estimate heritability, correlation and direct and indirect effects towards cane yield and sucrose content in sugarcane (*Saccharum officinarum* L.). Sixteen clones were evaluated in a replicated field experiment at Sugarcane Research Programme, Jitpur, Bara, Nepal in 1999-2000 for eight morphological and three juice quality characters under irrigated conditions. Analysis of variance revealed significant differences for all the characters except juice purity. The genotypes BO.128 gave the highest cane yield and sucrose percent in juice. High heritability (h^2) estimates were associated with stalk weight, stalk length, internode length, cane yield, millable cane number, germination, and stalk diameter whereas, moderate values were obtained for internode number. Juice quality character showed lower estimates of h^2. Cane yield showed significant positive correlations with stalk length, stalk weight, internode number and internode length. Internode length was significantly positively correlated with brix and sucrose in juice. Path coefficient analysis showed that stalk weight and stalk length were the most important components of cane yield. Germination at 45 days after planting and millable cane number could also be considered important due to their moderate positive direct effect on cane yield. Results suggest that for increasing sucrose percent emphasis should be given to brix percent and purity percent in juice while selecting for clones in sugarcane.

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उखुमा खण्डहरुको सम्वन्ध

सारांश

नाम : रेवती रमण चौधरी
सिमेष्टर र भर्ना मिति : २०५५
मुख्य विषय : वाली प्रजनन्
मुख्य सल्लाहकार : डा० राम चन्द्र शर्मा

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विभाग : वाली प्रजनन्

सोह्र वटा उखुका जातहरुलाई चार वटा पूर्ण खण्डको (replication) आधारमा जितपुरमा २०५५ सालमा एघार वटा विभिन्न गुणहरु र रस सम्वन्धी अध्ययन गर्न, सिंचित क्षेत्रमा लगाएको थियो। जातको विविधता उत्पादन र चिनिको गुण सम्वन्धमा तथा त्यसको अप्रत्यक्ष प्रभाव वारे अध्ययनको उद्येश्य रहेको थियो। विविधताको आधारमा रसको शुध्दता बाहेक अन्य सवै गुणहरुमा ति जातहरुमा भिन्नता पाईयो। जात वी. ओ. १२८ ले उखुको उत्पादन तथा रसादीमा सवैभन्दा राम्रो पाईयो। सर्व गुणहरुमा वंशानुगत भिन्नता भन्दा वाह्य गुणहरुको फरकता, लांक्राको तौल र उखुको उत्पादनमा बढी देखिन्छ भने ४५ दिनमा उमारशक्ति , पेलनीय उखुको संख्या, गांठ विचको संख्या र लांकाको लम्वाई मध्यम खालको भएको पाईयो। उखुको लांकको तौल, लम्बाई, गांठ बीचको दूरी, पेलनीय उखु र उत्पादनमा हेरीट्यावीलीटी (heritability) बढी ४५ दिनमा उमारशक्ति र गांठ संख्यामा मध्यम र रसादीमा कम भएको पाईयो। उमारशक्ति, लांक्राको तौल, उखु उत्पादन, लांकाको लम्बाई, पेलनिय उखु र गांठ वीचको दुरीमा वंशाणुगत संवृध्दि मध्यम थियो भने गाठ वीचको संख्या, गांठको व्यास र रसमा कम भएको पाईयो। उखु उत्पादन र लांकाको लम्वाई तथा तौल वीच बढी सम्वन्ध भएको र उखु उत्पादन संग गांठको संख्या,गांठ विचको दुरी र रस विचको मध्यम खालको सम्वन्ध भएको पाईयो। रसमा चिनिको मात्रा र गांठ विचको दुरी साथै व्रिक्स (brix) वीचको सम्वन्ध सकारात्मक भएको देखियो। खण्ड खण्ड को अन्तरसम्वन्ध वाट लांक्राको तौल र लम्वाई उत्पादमा बढी महत्वपुर्ण भएको पाईयो र ४५ दिनमा उमारशक्ति, पेलनिय उखु संख्या र व्रिक्सहरुको उखुउत्पादनमा मध्यम खालको सकारात्मक असर भएको र यसवाट ति गुणहरुलाई बढी उत्पादन भएक् छनौट गर्दा ध्यान दिनु पर्ने देखिन्छ। उखुमा चिनिको मात्रा बढाउनको लागी छनौट गर्दा ब्रिक्स र रसमा शुध्दताको प्रतिशत जस्ता गुणहरुलाई ध्यान दिनुपर्ने देखिन्छ।

डा० राम चन्द्र शर्मा
मुख्य सल्लाहकार

रेवती रमण चौधरी
शोधकर्ता

1. INTRODUCTION

Sugarcane is an important sugar crop in Nepal as well as in other tropical and subtropical countries of the world. It is the most important cash crop in terms of cultivated sugarcane area and its contribution to the total gross return of the country (Shrestha, 1996, personnel communication). It is an important industrial crop in Nepal. It provides employment to a large number of people from field to factory (SRP, 1999). Sugarcane yield and juice quality are the major factors for determining the performance of a sugarcane cultivar. It is the only raw material available for the production of sugar and jaggery in Nepal.

In Nepal, large-scale cultivation of sugarcane started in the year 1946 with the establishment of the first sugar factory in Morang district. Area and production of sugarcane increased considerably after the establishment of two more sugar factories: Birgunj Sugar Factory and Mahendra Sugar Mills, which were established at Birgunj (Parsa) and Bhairahawa (Rupandehi), respectively, during 1964. At present there are ten sugar factories under operation. Area, production and productivity of sugarcane in Nepal were 44800 ha, 1762580 t and 36.1 t ha^{-1}, respectively during 1997/98 (SRP, 1999). Major sugarcane area is concentrated around sugar mills in Sunsari, Morang and Siraha districts in the eastern region, Bara, Parsa, Rautahat, Sarlahi, Mahottary and Dhanusha in the central region, Nawalparasi, Kapilbastu, and Rupandehi in the western region and Dhangadi and Kanchanpur in the far western region.

Sugarcane is a wind – pollinated highly polyploid crop in which regular Mendelian segregations are neither expected nor observed (Blackburn, 1984). Crosses between clones display large variability and it is among such F_1 progenies that breeders could seek new varieties. Hundreds of seedlings are produced from a single cross, every one of which is a potential new variety of possible commercial worth. There is neither sufficient land nor money for each progeny to be raised and tested against standard varieties in the controlled experiments. The subsequent selection in successive clonal generations is a widely practiced breeding methodology for development of sugarcane varieties for commercial cultivation.

Slow response to selection for yield in early generation is one of the serious limitations to progress in sugarcane breeding. Yield in sugarcane is a complex trait that combines cane yield and sugar content in juice. These characters are dependent on a number of component attributes. Polygenic control of yield and its component characters and its interaction with environment make the selection for cane yield more difficult.

A clear understanding of genetic variability for quantitative characters in breeding material is essential to the breeders, since only the genetic portion of the total variability contributes to genetic gain from selection. Similarly, heritability estimates provides a measure of the effectiveness with which selection can be expected to exploit the genetic variability. However, genetic advance is a more accurate measure of genetic progress under directional selection practiced for quantitative traits.

Correlations between characters are a frequent feature of plant breeding. The associations of several quantitative characters with yield are important in selection. Selection pressure may be more rationally exerted on any of the characters that show close association with yield. Path coefficients are excellent means of studying direct and indirect effects of interrelated components of a complex trait.

Hence the knowledge of genetic variability present in the population and correlation coefficients of characters is very essential before launching an efficient breeding programme (Singh et al. 1981). These aspects are more helpful in providing an idea about a particular character on which a greater emphasis should be given while selecting suitable plant type to be used for breeding purposes in the improvement of crops. The selection practice is done in seedling as well as clonal generations for evolving high yielding varieties along with desirable levels of quality characters.

Selection for desired traits is the major objective in sugarcane breeding program. Information on genetic variation for important traits and their interrelationship is needed. Therefore, to obtain basic understanding on these aspects, this study was conducted with the following objectives in a set of 16 genotypes of sugarcane

1. To estimate the heritability of different characters.

2. To find out the association among of different traits including sugarcane yield.

3. To know the direct and indirect effects of germination at 45 days after planting, stalk length, diameter and weight, internode number and length, millable cane number, cane yield and brix, sucrose and purity percent in juice towards cane yield through path coefficient analysis.

2. LITERATURE REVIEW

Higher economic yield is the main breeding objective in all the crops, however, generally yields shows low heritability. Yield is a complex quantitative character governed by a large number of genes and is greatly affected by environmental fluctuations, hence the selection of superior genotypes based on yield *per se* is not effective. One approach towards the improvement of yield is selection for the components of yield. Being components, they may be less influence by environments compared to yield.

In crop plants, the segregating pattern of yield and most of the yield components are continuous and their phenotypic expressions are highly influenced by environmental fluctuations. Analysis of genetic basis of these polygenic characters into discrete phenotypic classes for effective selection is not possible within Mendelian framework. In such situations, the genetic variation and the level of heritability of the characters in a population are useful parameters for estimating response to selection (Kadir et al., 1996).

2.1. Genotypic and Phenotypic Variance:

The knowledge of genetic variation in a crop species is important as it provides a basis for effective selection (Singh, 1993). The total variation in a population arises due to genotypic and environmental effects. Phenotypic variation includes both genetic and environmental components. As a result, its magnitude differs under different environmental conditions. Genotypic variation, on the other hand, is the component of variation, which is due to the genetic differences among individuals within a population, and is of main concern to plant breeders.

Barber (1916) at Sugarcane Breeding Institute, Coimbatore observed variability in seedling raised from fluffs of sugarcane and found large variation for leaf width, girth of stalk and sucrose percent in juice. The high genotypic variation for cane yield was reported by Singh and Sangawan (1980), Shah et al. (1966), Sahi et al. (1977), Balasundarum and Bhagyalakshmi (1978), Nair et al. (1980), Reddy and Reddi (1986), Ghosh and Singh (1996).

Yield in sugarcane is mainly a function of millable cane at harvest which in-turn depends on the number and time of production of tillers followed by their mortality. The high genotypic variance for millable cane was reported by Balasundarum and Bhagyalakshmi (1978), Nair et al. (1980), Reddy and Reddi (1986) and Ghose and Singh (1996). Kumar (1998) and Kamat (2000) reported high values of genotypic and phenotypic variances for germination at 45 days after planting, tillers at 120 days after planting and number of shoots at 240 days after planting. Singh and Sangawan (1980), Shah et al. (1966) and Kumar (1999) reported high magnitude of genetic variance for stalk length. The role of environment on inheritance of internode number and internode length was found non-significant (Singh and Sangwan, 1980). Stalk weight being directly related with cane yield provides a good measurement for selection. Kumar (1997) reported that differences among phenotypic and genotypic variances were wider for stalk weight, sucrose percent and brix at 300 days after planting. Verma et al. (1988) studied genetic variability from data on ten characters in eleven lines of sugarcane and their twenty-four F_1 hybrids. They found that information on phenotypic and genotypic coefficients of variation could be used in selection for brix, millable cane per clump, CCS per cane, stalk weight and internodes per cane.

2.2. Genotypic and Phenotypic Coefficient of Variation:

Genotypic and phenotypic coefficients of variation determine the magnitude of dependence of characters manifestation on environmental factors. High genotypic and phenotypic coefficients of variation for cane yield were obtained by Singh and Sangwan (1980), Kumar (1997) and Mishra (1988). However Kamat (2000) reported moderate genotypic and phenotypic coefficients of variation for cane yield. Singh et al. (1981), Kumar (1997) and Mishra (1988) reported high value of genotypic as well as phenotypic coefficients of variation for stalk length. High genotypic and phenotypic coefficients of variations were reported by many workers for stalk weight and millable cane (Stevension, 1954, Singh and Sangwan (1980) and Kamat, 2000). For juice quality Kumar (1997) and Ghosh (1991) reported low genotypic and phenotypic coefficient of variation. But Singh et al. (1994) reported high phenotypic coefficients of variation for sucrose percentage and commercial cane sugar per hectare. Stevension (1954) observed that coefficient of variation for juice brix in the seedling population were higher than those for clonal material. Tillers at 120 and 240 days after planting and germination at 45 days after planting showed high genotypic and phenotypic coefficients of variation (Ghosh, 1991; Kumar, 1997 and Kamat, 2000).

2.3. Heritability:

The concept of heritability originated as an attempt to describe whether variations observed among individual arose from the differences in genetic makeup of the individuals or resulted from different environmental forces. In crop improvement only the genetic component of variation is important since it is transmitted to the next generation. Knight (1918) defined heritability as the portion of the observed variance for which difference in heredity is responsible. Estimates of heritability serve as a useful guide to the breeder. If heritability of a character is very high, e.g. 0.8 or more, selection for such a character should be fairly easy. This is because there would be close correspondence between the genotype and phenotype due to a relatively small contribution of the environment to the phenotype (Singh, 1993). In case heritability estimates for a character is low, say less than 0.4, selection may be considerably difficult or virtually impractical due to the masking effect of the environment on genotypic effects (Singh, 1993). The heritable portion of the variability can not be judged by the genotypic coefficient of variation alone. It is heritability, which can give true picture of heritable portion of variability together with genotypic coefficient of variation (Singh et al. 1981).

Sugarcane is a vegetatively propagated crop. In asexually reproduced plants any combination of genetic factors that yields a superior genotype can be utilized through clonal propagation. Heritability in the broad sence would have meaning for asexually reproduced plants since all genetic variability is usable. A number of scientists have estimated heritability based on the variability between available clones. Keller and Likens (1955) estimated heritability in hops. Burton and Devane (1953) estimated heritability in tall fescue. In sugarcane crop several experiments were conducted on heritability. Some of them are reviewed below briefly.

High heritability estimates for stalk weight were reported by many workers (Nair et al., 1980; Singh et al., 1994 and Kumar, 1999). However, Singh et al. (1981) reported moderate estimate of heritability for stalk weight. Like wise high heritability estimates for stalk length was also reported by Singh et al. (1994), Ghosh and Singh (1996), Singh and Sangwan (1980), Kumar (1997) and Kamat (2000). But Singh et al. (1981) observed moderate estimates of heritability for stalk length. High heritability estimates for cane yield were reported by Singh and Sangwan (1980), Ghosh and Singh (1996), Kumar (1997) and Balasundarum and Bhagyalakshmi (1978). High heritability estimates for millable cane was reported by Nair et al. (1980), Singh et al. (1994), Ghosh and Singh (1996) and Kumar (1996). Stalk diameter showed high heritability estimates in the studies reported by reported by Singh and Sangwan (1980), Mishra (1988) and Singh et al (1994). However, Kumar (1997) reported low heritability estimates for stalk diameter. For juice quality characters low heritability estimates were reported by Sahi et al. (1977) and Kumar (1997).

On the other hand, Singh et al. (1981), O' Reilly et al (1995) and Mishra (1988) found high estimates of heritability for juice quality characters. High estimates of heritability for internode number and internode length were reported by Singh et al. (1994) and Singh sngwan (1980). Germination at 45 days after planting, and the number of shoots at 90, 120 and 240 days after planting also had high heritability estimates in the studies conducted by Ghosh and Singh (1996) and Kumar (1997).

Shah et al. (1966) studied heritability estimates in two groups (North and South Indian) of sugarcane varieties for six agronomic characters. The heritability estimates for these characters ranged from 58 to 93 %. Sahi et al. (1977) studied plant and ratoon crops and found heritability ranging from 86 to 96% in plant crop and 74 to 91 % in ratoon crop for ten characters. Heritability estimates were low for quality characters.

The broad sence heritability can be estimated from analysis of variance table, or from the variances in P_1, P_2, F_1 and F_2, generations or from the parent-offspring regression (Singh, 1993). Shankaranarayan and Shunmugasundaram (1981) reported that heritability values in the narrow sence recorded by parent progeny regression and intra class variation method were almost similar for leaf width. For brix, the heritability of intra-class correlation agreed well with the heritability value obtained through maternal parent versus parent progeny regression method. Hogarth et al. (1981) reported that heritability was low for all characters in sugarcane crop on both individual and family base, indicating that selection of clones from the progeny population, as potential parents would not be successful. On the family basis, the estimates of heritability from the parent off spring regression were higher than those from the comparable progeny analysis.

2.4. Correlation:

The statistic that measures the relationship between two or more variables is known as correlation coefficient. It is represented by '*r*'. The correlation indicates overall association between characters due to linkages, pleiotropy and physiological association. For rational improvement of yield and its components, the understanding of correlation is very useful. A positive value of *r* shows that the changes of two variables are in the same direction, i.e. high values of one variable are associated with high values of other and vice versa. When *r* is negative, the movement is in opposite directions, i.e. high values of one variable are associated with low values of other. The correlation coefficient is independent of the unit of measurement. Its value lies between -1 and 1. It measures the degree and direction of association between two or more variables.

Information on the association among different characters helps in formulating sound selection techniques. Most of the economic characters in commercial sugarcane hybrids are of complex nature. Barber (1916) attempted to systematically correlate some of the morphological characters with juice quality. Since then several investigations were carried out on relationship between economic characters with contradictory results.

A positive and highly significant correlation between stalk yield and its components, viz. number of millable cane number, stalk length, and stalk weight was reported by Hebert (1965), Brown et al. (1969), Miller and James (1974), Balasundarum and Bhagyalakshmi (1978) and Punia et al. (1983). Cane diameter showed a significant positive correlation with cane yield (Punia et al., 1983 and Hooda et al., 1979). A negative association between the number of millable cane and stalk thickness was reported by Balasundarum and Bhagyalakshmi (1978). Madhavi et al. (1991) found that stalk weight was positively associated with diameter and length. A positive association was also found between volume and diameter, weight and density, length and number of internodes, and average internode length and number of internodes. Kumar (1999) observed that tillers at 120 days, number of shoots at 240 days, and number of millable cane had significant positive correlations with cane yield.

Cane yield and sugar yield are equal important from selection point of view. Many workers have studied association between juice quality characters and morphological characters. The association between cane yield and sucrose percent was found non-significant (Punia et al., 1983 and Hooda et al., 1988). Stalk yield had a non-significant correlation with sucrose percent and CCS percent (Balasundarum and Bhagyalakshmi, 1978 and Hebert, 1965). Balasundram and Bhagyalakshmi (1978) reported a significant positive correlation of stalk yield and its components. Stalk thickness and stalk weight were also significantly and positively correlated with each other and with sucrose and sugar percentage. Singh et al. (1981) observed positive genotypic and phenotypic correlations of brix with number of millable canes, number of internodes in cane and number of green leaves. Stevension (1954) found a low positive correlation between cane weight and brix. Nageswararao and Ethirajan (1984) observed that sucrose percent in the clones is directly related to the brix. The sucrose was more influenced by number of millable canes and girth of stalk but not by either plant height or leaf characters.

Verma et al. (1988) found significant positive correlation among the number of millable canes per clump, internodes per cane, stalk weight, brix and CCS per cane. A significant positive association of stalk girth was found with stalk weight and CCS per cane. Therefore, millable canes per clump, internodes per cane stalk weight, brix, CCS per cane and stalk girth should be given due weightage during selection. Ghosh (1991) reported that the number of shoots at 90 and 120 days after planting, number of millable canes, cane yield and germination at 45 days after planting were significantly positively correlated among themselves, but their association with juice brix at 300 days after planting was non-significant.

2.5. Path Coefficient Analysis:

Path analysis is a standardized partial regression coefficient, which splits the correlation coefficients into the measures of direct and indirect effects of a set of independent variables on the dependent variable. Wright originally developed path coefficient analysis, but Dewey and Lu (1959) first used for plant selection.

The path analysis unravels whether the association of a set of characters with dependent character is due to their direct effect, or is a consequence of their indirect effect via some other trait. If the cause and effect relationship is well defined, it is possible to represent the whole system of variables in the form of a diagram, known as path diagram. The advantage of path diagram is that a set of simultaneous equations can be written directly from the diagram and a solution of these equations provides information on the direct and indirect contribution of these causal factors. Relationship between cane yield and its component characters does not represent an exact picture of the relative importance of direct and indirect effects of the various yield contributory characters. Path coefficient analysis provides a more reliable assessment of the relationship between cane yield and its component characters as it permits the separation of the correlation coefficient into components of direct as well as indirect effects.

Based on published results stalk weight showed a direct positive effect on cane yield (Punia et al., 1983; Reddy and Reddi, 1986 and Hooda et al., 1988). Kang et al (1983) indicated that stalk length was important for cane yield. A direct effect of millable cane on cane yield was observed by Balasundarum and Bhagyalakshmi (1978), Kang et al. (1983), Punia et al. (1983), Reddy and Reddi (1986), Hooda et al. (1988), Xie et al (1989) and Chaudhary and Singh (1994). For increasing sucrose content direct selection for brix in juice was found desirable (Nageswara and Ethirajan, 1984). Miller (1977) reported that stalk number, stalk diameter, stalk length, and brix were important in determining brix on a per plant basis. Hooda et al. (1979) found that cane weight was the main character contributing directly to yield followed by plant height and brix value. These characters are recommended as indices for selection at the settling stage. Xie et al. (1989) worked out path analysis of four yields related characters in crossbred progenies at the seedling stage (1st year) and the clonal stage (2nd year). They found that stalk number was the most useful trait when selecting for cane and sugar yields. Gravois et al. (1991) reported that purity and stalk weight were the main factors responsible in increasing sucrose content. Indirect effects suggested that selection for low levels of pith would increase level of brix and purity.

3. MATERIALS AND METHODS

Sixteen clones of sugarcane developed at different research stations in India that belonged to different maturity groups were planted in a randomized block design with four replications at Sugarcane Research Programme, Jitpur on February 7,1999 (Table 1). The plots of the 6 m x 5.4 m sizes were planted as six rows of 6 m. length each at 90 cm row spacing. All observations were recorded on 4 m row length of four middle rows. The observations were recorded for germination percentage at 45 days after planting, stalk length, diameter and weight, internode number and length, millable cane number, cane yield and brix, sucrose and purity percent in juice at harvesting time.

Table.1. Name and place of origin of 16 clones of sugarcane included in the study.

S.No.	Genotypes	Place of origin	Maturity group
1	Co.92030	Sugarcane Breeding Institute, Coimbatore, India.	Early
2	Jeetpur-2	Sugarcane Breeding Institute, Coimbatore, India.	Early
3	CoSe.95421	Genda Singh Sugarcane Breeding and Research Institute, Seorohi, India.	Early
4	Co.94022	Sugarcane Breeding Institute, Coimbatore, India.	Early
5	BO.128	Sugarcane Research Institute, Pusa, India.	Early

6	CoSe.95422	Genda Singh Sugarcane Breeding and Research Institute, Seorohi, India.	Early
7	Co.94023	Sugarcane Breeding Institute, Coimbatore, India.	Early
8	CoP.94182	Sugarcane Research Institute, Pusa, India.	Mid
9	CoSe.93235	Genda Singh Sugarcane Breeding and Research Institute, Seorohi, India.	Mid
10	BO.110	Sugarcane Research Institute, Pusa, India.	Mid
11	CoSe.94423	Genda Singh Sugarcane Breeding and Research Institute, Seorohi, India.	Mid
12	CoB.94163	Sugarcane Breeding Station, Bethuadahari, India	Mid
13	CoSe.92423	Genda Singh Sugarcane Breeding and Research Institute, Seorohi, India.	Mid
14	CoSe.95426	Genda Singh Sugarcane Breeding and Research Institute, Seorohi, India.	Mid
15	CoSe.92430	Genda Singh Sugarcane Breeding and Research Institute, Seorohi, India.	Mid
16	BO.91	Sugarcane Research Institute, Pusa, India.	Late

The plot was first ploughed with a mould board plough followed by two cross ploughed with a disc harrow and then with a cultivator before planting. Planking followed each harrow and cultivator ploughing. Proper leveling was done after making bund for plot division manually. At the time of planting, furrows were opened 90 cm. apart with the help of a spade for planting of cane. Healthy canes of different genotypes from upland spring planted well mannured and well irrigated sugarcane crops were selected. The setts with three eyes were cut with a sharp weapon (locally called *Garansi*) and each sett was visually examined for disease and pest infection. The healthy and sound setts were dipped in to 0.1 % Bavistine solution for 5 minutes before planting. Fertilizers were applied at the rate of 75, 60, and 40 kg ha^{-1} of N, P_2O_5 and K_2O respectively, prior to planting. Besides, mustard oil cake was applied @ 0.6 t ha^{-1} mixed with soil in the furrows. The treated setts were planted @ 12 buds $meter^{-1}$ in the furrows. A thin layer of Thimet granules 10-G @ 10 kg ha^{-1} active ingredient was placed over the setts, and the furrows were immediately covered with side soil by a spade followed by planking to make the surface plain, compact and free from clods. Three hand weedings at 45, 90 and 120 days after planting were done followed by two inter-cultivations with spade just after first and second hand weeding. Three irrigations were applied at 50, 95 and 126 days after planting. At maturity the crop was harvested between Feb. 9 and 12, 2000, and yield was recorded in net area after adding the cane weights of samples recorded for different observations.

3.1. Data recording:

Ten sugarcane plants were randomly selected at harvesting time and observations were taken for stalk length, diameter, weight, internode number and length, brix, sucrose and purity percent in juice.

3.1.1. Germination:

Germination of the buds of three budded setts was recorded at 45 days after planting by counting the number of individual seedling germinated. Germination percentage was calculated as:

$$\text{Percent germination} = \frac{\text{Number of germinated shoot}}{\text{Number of eyes planted}} \times 100$$

3.1.2. Stalk length:

Measurement of the whole length of the cane was taken as recommended commercially for crushing purpose in the sugar mill. The average length was calculated.

3.1.3. Stalk diameter:

Thickness of the selected canes was measured by slide caliper at bottom, middle, and top internodes and averaged. It was measured at harvesting time.

3.1.4. Stalk weight:

The selected canes were weighed and average stalk weight was determined.

3.1.5. Internode number:

Internode numbers were counted in the ten selected canes. The average internode number was calculated by dividing the sum of total number by ten.

3.1.6. Internode length:

The ten selected canes were measured by scale at bottom, middle and top internodes and averaged by dividing the sum of internode length by thirty.

3.1.7. Millable cane number:

The number of millable cane was counted at harvesting time from the net area (4m x 3.6m) in each plot. The full-grown canes, which could have been used for crushing, were taken into account. Finally the number of millable cane was converted into per hectare basis.

3.1.8. Cane yield:

Crop was harvested at the ground level. Stripping and detopping were done properly. Total millable canes per net area (4 m x 3.6 m) were weighed. Yield was adjusted after adding weights of cane removed previously for juice analysis and other observations. Finally, it was converted into t ha^{-1}.

For chemical observations a clump of plant was taken from each plot at harvesting time. Cane was crushed in power crusher and juice collected separately for further analyses.

3.1.9. Brix percent of juice:

This was determined by floating brix hydrometer in juice, kept in a cylinder and making necessary correction for temperature in brix hydrometer reading.

3.1.10. Sucrose percent of juice:

Sucrose percent of juice was determined by poleriscope reading after clearification of juice and making necessary calculation and correction for temperature.

3.1.11. Purity percent of juice:

This indicates percentage of sucrose in the total solid of juice (brix) and was calculated as:

Purity percent of juice = (sucrose percent / brix percent) * 100.

3.2. Statistical Analysis:

Mean performance on per plot basis was obtained by taking the average performance of the plants over the blocks of particular genotype. Analysis of variance was computed for all characters using INSTAT software. An outline of the ANOVA with expected mean square is given in Table 2.

Table-2. Analysis of variance and expectation of mean squares

Source of variation	df.	M.S.S.	E.M.S.
Replications	r-1	$\frac{R.S.S.}{(r-1)}$	
Genotypes	v-1	$\frac{V.S.S.}{(v-1)}$	$6^2_e + r\,6^2_g$
Error	(r-1)(v-1)	$\frac{E.S.S.}{(r-1)(v-1)}$	6^2_e

Where,

r = Number of replication

v = Number of genotypes

6^2_g = Genotypic variance

6^2_e = Environmental variance

df = Degree of freedom

M.S.S. = Mean sum of squares

V.S.S. = Genotype sum of square

E.S.S. = Error sum of square

In order to assess whether the difference between the treatments were significant, DMRT was done by using MSTAT software.

3.3. Genotypic and Phenotypic variance:

Genotypic and phenotypic variance were obtained from the analysis of variance table as follows:

$$\text{Genotypic variances } (6^2_g) = \frac{M.S.V. - M.S._e}{r}$$

Where,

M.S.V. = Mean sum of square due to genotypes

M.S.e. = Mean sum of squares due to error, and r = Replication number

Phenotypic variance (σ^2_p) = $\sigma^2_g + \sigma^2_e$

3.4. HERITABILITY:

Heritability in broad sense (h^2_{bs}) was calculated as the ratio of genetic variance to the phenotypic variance. It is calculated by the formula suggested by Hanson *et al.* (1956).

$$\text{Heritability (H)} = \frac{\sigma^2_g}{\sigma^2_g + \sigma^2_e}$$

$$= \frac{\sigma^2_g}{\sigma^2_p}$$

where,

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

σ^2_e = Environmental variance.

3.5. CORRELATION COEFFICIENT:

Correlation coefficient measures the magnitude of relationship between two or more variables based on the amount of variability in one character that can be explained by a linear function of the other. Correlation coefficient of all possible combinations between traits was calculated by using instat software.

$$\text{Correlation coefficient } (r) = \frac{\Sigma XY - \dfrac{(\Sigma X)(\Sigma Y)}{N}}{\left[\left\{(\Sigma X^2) - \dfrac{(\Sigma X)^2}{N}\right\}\left\{(\Sigma Y^2) - \dfrac{(\Sigma Y)^2}{N}\right\} \right]^{1/2}}$$

Where,

r	=	Correlation Coefficient
ΣXY	=	Sum of the products of two variable 'X' and 'Y'.
X^2	=	Sum of squares of variable 'X' .
Y^2	=	Sum of squares of variable 'Y'.
N	=	Number of pairs of observation 'X' and 'Y'.

The computed value of correlation coefficient was put to comparative study with the corresponding tabular r-value obtained from table at a specified level of significance (5 and 1%) with (n-2) degree of freedom, where 'N' is the number of paired observations from which computed '*r*' value was obtained.

3.6. PATH COEFFICIENT ANALYSIS:

The total correlation coefficient of various yield contributory characters with regard to cane yield was partitioned into the components of direct and indirect effects by path co-efficient analysis following the method adopted by Dewey and Lu (1959).

Path analysis is the ratio of standard deviation of the effect due to a given cause to the total standard deviation of the effect. As for instance, if cane yield (Y) is the function or effect and X1 (one of the various components or casual factors of cane yield), the path coefficient for the path from X1 to the effect Y is ($\sigma X1/ \sigma y$). It is, in fact, standardized partial regression coefficient.

The path coefficients were obtained by solving a set or simultaneous equations of the form:

$$r_{ny} = P_{ny} + r_{n2}\ P_{2y} + r_{n3}\ P_{3y} + \ldots\ldots\ldots + \ldots\ldots\ldots$$

Where,

r_{ny}	=	Correlation between the n^{th} character and cane yield
P_{ny}	=	Path coefficient between the nth character and cane yield
N	=	1, 2, ... n, i.e. various causal factors.
r_{n2}, r_{n3} etc.	=	Denote correlation between n^{th} character and each of other yield contributory characters, designated as 1, 2, 3 ......

respectively, in turn.

Considering all the simultaneous equation, correlation matrices of the following form were prepared.

Matrix 'A' = Matrix 'B' Matrix 'C'

$$
\begin{bmatrix} r_{1y} \\ r_{2y} \\ \cdot \\ \cdot \\ \cdot \\ r_{ny} \end{bmatrix}
=
\begin{bmatrix} r_{11} & r_{12} & \ldots\ldots & r_{1n} \\ r_{21} & r_{22} & \ldots\ldots & r_{2n} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ r_{n1} & r_{n2} & & r_{nn} \end{bmatrix}
\begin{bmatrix} P_{1y} \\ P_{2y} \\ \cdot \\ \cdot \\ \cdot \\ P_{ny} \end{bmatrix}
$$

or A=B.C.

The 'B' matrix was inverted to get the inverse value of matrix 'B'.

The path coefficients were obtained by multiplying vector 'A' with inverse of Matrix 'B'

$$P_{iy} = B^{-1} x A$$

Where,

P_{iy} = direct path coefficient.

The direct effect of a particular character 'i' through the other character 'j' was estimated by the multiplication of direct path of j^{th} character and corresponding correlation coefficient between 'i' and 'j' respectively.

Indirect effect $= r_{ij} \cdot P_{jy}$

In the present investigation, the path coefficient for simple correlation matrices was obtained using the above procedure. The effect of residual factors i.e., the variation in cane yield that is not accounted for by different causal factors under consideration was estimated as follows:

Residual effect $({}^{P}ry) = [1 - \Sigma({}^{P}iy \cdot {}^{r}iy)]^{½}$

Where,

P_{iy} = Path coefficient of i^{th} characters for cane yield (Y)

r_{iy} = Simple correlation coefficient between i^{th} character and cane yield

3.7. Scales for path coefficients used to interpret results of this study was according to the method given by Singh and Narayanan (1993), which is given below.

Values for direct or indirect effects	Rate or scale
0.00 to 0.09	Negligible
0.10 to 0.19	Low
0.20 to 0.29	Moderate
0.30 to 0.99	High
More than 1.00	Very high

4. RESULTS

4.1. Analysis of variance:

There were significant differences among the sixteen genotypes for germination, stalk length, stalk diameter, internode number, internode length, stalk weight, millable cane, brix and sucrose percent in juice and cane yield (table 3). The genotypes did not differ significantly for juice purity. The genotypic means of different characters are presented in Table 4.

4.1.1. Cane yield:

A higher cane yield was produced by the genotypes BO. 128 (75.265 t ha^{-1}), CoSe. 95422 (69.2 t ha^{-1}) and CoSe. 92430 (67.0125 t ha^{-1}) (Table 4). Late maturing genotype BO. 91, occupying more than 60% of the total cane area in Nepal (SRP, Jitpur, 1998) produced 57.987 t ha^{-1} cane, which was about equal to early maturing genotype Jeetpur-2 (66.0876 t ha^{-1}) and mid late popular genotypes BO. 110 (60.625 t ha^{-1}). Co. 94022 gave the lowest cane yield (26.792 t ha^{-1}).

Table. 3. Analysis of variance, components of variances and heritability (broad sense) for stalk characters in 16 sugarcane genotypes grown at Jitpur, Nepal in 1999-2000.

Components	df	Cane yield ($t\ ha^{-1}$)	Germ. 45 DAP (%)	Stalk length (cm)	Stalk diameter (cm)	Internode no.	Internode length (cm)	Mill. cane ($x\ 10^3$ ha)	Stalk weightt (kg.)	Brix (%)	Sucrose (%)	Purity (%)
Replication	3	44.7	6.4	71.1	0.008	0.7	0.2	82.8	0.0008	0.06	0.13	0.3
Genotype	15	611.1**	172.9**	4038.7**	0.046**	31.2**	4.7**	1322.2**	0.077**	1.23*	1.39**	5.15
Error	45	30.7	11.8	140.8	0.004	4.2	0.2	74.0	0.0025	0.32	0.3	3.52
6^2 p		175.8	52.1	1115.3	0.015	10.9	1.3	386.1	0.0210	0.55	0.57	3.93
6^2 g		145.1	40.3	974.5	0.010	6.8	1.1	312.0	0.0190	0.23	0.27	0.41
6^2 e		30.7	11.8	140.8	0.004	4.2	0.2	74.0	0.0025	0.32	0.3	3.52
H.(%)		82.6	77.3	87.4	71.0	61.8	83.8	80.8	88.2	42.1	47.5	10.4

*, ** significantly greater than zero at 0.05 and 0.01 probability levels, respectively. Germ.45 DAP = germination at 45 days after planting, 6^2 p = phenotypic variance, 6^2 g = genotypic variance, 6^2 e = environment variance, H (%) = heritability percentage.

Table 4. Mean values of different characters measured on 16 sugarcane genotypes grown at Jitpur, Nepal in 1999- 2000.

Genotypes	Cane yield ($t\ ha^{-1}$)	Germ. 45 DAP† (%)	Stalk length (cm)	Stalk diameter (cm)	Inter node no	Internode length (cm)	Stalk weight (kg)	Millable Cane ($000\ ha^{-1}$)	Brix (%)	Sucrose (%)	Purity (%)
Co.92030	47.33 g	37.27 d-f	159 g	1.74 c-e	16 e	11.1 ab	0.418 fg	118.60 b	19.79 b-e	18.42 a-c	93.06
Jeetpur-2	66.09 b-d	27.29 h	235 a	1.81 bc	25 ab	9.9 d-g	0.761 a	81.93 cd	20.62 ab	18.71 ab	90.76
Co.Se. 95421	58.00 de	39.46 c-e	199 cd	1.77 b-d	21 cd	10.8 bc	0.539 cd	119.40 b	20.52 a-c	18.69 ab	91.11
Co.Se.92430	67.01 a-c	33.36 fg	216 bc	1.74 c-e	26 a	9.4 fg	0.756 a	93.06 c	19.85 b-e	17.57 c-f	90.65
Co.94022	26.79 h	27.18 h	129 h	1.57 g	20 cd	7.8 I	0.275 h	78.80 d	20.22 a-d	18.39 a-d	90.96
Co.P 94182	56.89 ef	36.55 d-g	190 de	1.68 d-f	26 a	8.6 h	0.489 d-f	117.59 b	19.74 b-e	17.88 b-e	90.57
BO. 128	75.27 a	42.33 bc	229 ab	1.86 b	22 bc	11.5 a	0.743 a	115.51 b	20.98 a	18.79 a	89.57
Co.Se. 95422	69.20 ab	44.99 ab	217 ab	1.78 b-d	20 cd	9.3 g	0.529 cd	133.29 a	19.37 d-f	17.39 ef	89.75
BO. 91	57.99 de	44.25 a-c	199 cd	1.68 d-f	24 ab	9.9 d-g	0.545 cd	110.19 b	19.24 ef	17.48 d-f	90.89
Co.94023	33.91 h	31.95 gh	119 h	1.76 b-d	18 de	7.6 i	0.353 g	78.47 d	18.87 f	16.86 f	89.33

(Continue.....)

Table 4. (continued)

Co.Se. 93235	54.43 e-g	45.78 ab	173 fg	1.60 fg	20 cd	9.9 d-g	0.438 ef	122.45 ab	19.96 b-e	18.24 a-e	91.39
BO.110	60.63 b-e	48.35 a	193 de	1.71 c-e	21 cd	10.6 b-d	0.481 d-f	123.80 ab	20.05 b-e	17.50 d-e	88.15
Co.Se.94423	48.95 fg	41.24 b-d	186 de	1.71 c-e	20 cd	10.4 b-e	0.496 d-f	122.69 ab	19.92 b-e	18.16 a-e	91.25
Co.B. 94163	54.05 e-g	35.07 e-g	188 de	1.78 b-d	24 ab	10.0 d-g	0.588 bc	94.20 c	20.54 a-c	18.80 a	91.62
Co.Se.92423	59.26 c-e	32.22 g	190 de	2.02 a	21 cd	9.7 e-g	0.635 b	87.04 cd	19.51 d-f	17.84 b-e	91.55
Co.Se.95426	52.06 e-g	43.22 bc	179 e	1.65 e-g	22 bc	10.1 c-f	0.504 de	111.81 b	19.65 c-f	17.65 c-f	89.94
Mean	55.52	38.16	187.6	1.74	21.53	9.79	0.534	106.8	19.92	18.02	90.66
C.V. %	10	9	6.3	3.7	9	4.8	9.3	8.1	2.8	3	2.1

Values given in the column followed by the same letter do not differ at the 0.05 probability level according to Duncan's New Multiple range.

† = germination at 45 days after planting.

4.1.2. Germination at 45 days:

The midlate maturity genotypes BO. 110 gave the highest 48.35 germination percentage, which was similar to CoSe.93235 (45.783), CoSe. 95422 (44.988) and BO. 91 (44.25). Jeetpur-2 (27.287), Co. 94022 (27.177) and Co. 94023 (31.95) had low germination percentage.

4.1.3. Stalk length and diameter:

Jeetpur-2 (235 cm), BO. 128 (229 cm) and CoSe. 95422 (217 cm) had longer stalk compared to the rest of the genotypes. Co. 94022 (129 cm) and Co. 94023 (119 cm) had shorter stalk length. BO. 91 (199 cm), CoSe. 95421 (199 cm) and CoSe. 92430 (216 cm) had medium stalk length. BO.128 (1.86 cm), CoSe. 95422 (1.78 CM), Co. 94023 (1.76 cm), CoB. 94163 (1.78 cm), Jeetpur-2 (1.81 cm) and CoSe. 95421 (1.77 cm) had higher values for stalk diameter compared to others. Genotypes CoSe. 93235 (1.6 cm) and CoSe. 95426 (1.645 cm) had thinner stalk.

4.1.4. Internode number:

A higher number of internodes were recorded on the genotypes CoP. 94182 (26.00), CoSe. 92430 (25.75), Jeetpur-2 (24.75), BO. 91 (24.00), and CoB. 94163 (24.00), whereas Co. 92030 (16) and Co. 94023 (18) had fewer internodes.

4.1.5. Internode length:

Genotypes BO. 128 (11.5 cm) and Co. 92030 (11.1 cm) had higher internode length, whereas Co. 94022 (7.8 cm) and Co. 94023 (7.6 cm) had shorter internode length.

4.1.6. Stalk weight:

Jeetpur-2 (761 kg), CoSe. 92430 (756 kg) and BO. 128 (742 kg) had higher stalk weight of cane at harvest. Co. 94022 (1.275 kg) had the lowest stalk weight. The stalk weight of other genotypes ranged from 635 kg (CoSe. 92423) to 353 kg (Co. 94023).

4.1.7. Millable cane number:

The highest millable cane number was associated with Co. 95422 (133290 ha^{-1}), which was not significantly different from CoSe. 93235 (122.450 ha^{-1}), BO. 110 (123800 ha^{-1}) and CoSe. 94423 (122690 ha^{-1}). Co. 94022 (78798 ha^{-1}) and Co. 94022 (78473 ha^{-1}) had lower number of millable cane. The remaining genotypes showed a range from 119400 ha^{-1} (CoSe. 95421) to 81930 ha^{-1}. (Jeetpur-2) for millable cane number.

4.1.8. Brix percent in juice:

Genotypes BO. 128 (20.975), Jeetpur-2 (20.618), CoSe. 95421 (20.518), Co. 94022 (20.217) and Co. 94163 (20.535) had higher brix percent in juice. Co. 94023 (18.868) had the lowest brix percent.

4.1.9. Sucrose percent in juice:

The higher sucrose percent in juice was associated with BO. 128 (18.787), CoB. 94163 (18.802), Jeetpur-2 (18.707), CoSe. 95421 (18.692), Co. 92030 (18.415), Co. 94022 (18.39), CoSe. 93235 (18.24) and CoSe. 94423 (18.16). The lowest sucrose percent was found in Co. 94023 (16.857).

4.1.10. Purity percent in juice:

The range for juice purity was 88 .16 to 91.65 % but it did not differ significance among genotypes.

4.2. Heritability:

The considerable differences in heritability value for different characters were observed (Table 3). Among morphological characters, high heritability estimates were estimated for stalk weight (88.2%), stalk length (87%), internode length (84%), cane yield (83%), millable cane (81%), germination (77%) and stalk diameter (71 %), whereas, internode number (62%) showed moderate heritability estimates. For juice quality characters, low heritability was recorded for brix (42%) and sucrose content (47%). Juice purity showed the lowest heritability (10%).

4.3. Correlation Coefficient:

The pair wise simple correlation coefficients (*r*) among various characters are presented in Table 5. Cane yield was significantly positively correlated with stalk length (r = 0.948**) and stalk weight (r = 0.848**). There was a significant positive correlation of cane yield with internode number (r = 0.514*) and length (r = 0.583*). Cane yield was non-significant correlation with stalk diameter (r = 0.487), millable cane (r = 0.409), germination (r = 0.382), brix percent (r = 0.327), sucrose percent (r = 0.142) and purity percent (r = - 0.209). Germination showed a significant positive correlation with millable cane number (r = 0 .875**) and internode length (r = 0.509*) but a non-significant correlation with stalk length (r = 0.251), stalk diameter (r = - 0.206), internode number (r = -0.122), stalk weight (r = - 0.058), brix percent (r = - 0.101), sucrose percent (r = - 0.210) and purity percent in juice (r = - 0.330). Stalk length showed a significant positive correlation with stalk weight (r = 0.880**), internode number (r = 0.626**) and internode length (r = 0.559*) but non-significant correlation with remaining characters studied. Stalk diameter had a significant positive correlation with stalk weight (r = 0.610*) but

Table 5. Correlation coefficients among different characters in 16 sugarcane genotypes grown at Jitpur, Nepal in 1999-2000.

Character	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11 (Cane yield)
Germination (X 1)	0.251	-0.206	-0.122	0.509*	-0.058	0.875**	-0.101	-0.21	-0.330	0.382
Stalk length (X2)		0.418	0.626**	0.559*	0.880**	0.321	0.439	0.271	-0.135	0.950**
Stalk diameter (X3)			0.064	0.282	0.610*	-0.194	0.088	0.088	0.035	0.487
Internode number (X4)				-0.042	0.650**	-0.139	0.248	0.089	-0.144	0.514*
Internode length (X5)					0.466	0.550*	0.512*	0.497*	0.174	0.583*
Stalk weight (X6)						-0.058	0.420	0.266	-0.045	0.848**
Millable cane (X7)							0.022	0.001	-0.091	0.409
Brix % in juice (X8)								0.887**	0.091	0.327
Sucrose % in juice (X9)									0.500*	0.142
Purity % in juice (X10)										-0.209

*, ** Significantly greater than zero at 0.05 and 0.01 probability levels, respectively. Number of observations = 16.

non-significant correlations with internode number (r = 0.064), internode length (r = 0.282), millable cane (r = - 0.194), brix percent (r = 0.088), sucrose percent (r = 0.088) and purity percent in juice (r = 0.035). Internode number had a significant positive correlation with stalk weight (r = 0.650**) but non-significant correlation with internode length (r = - 0.042), millable cane (r = - 0.139), brix percent (r =0.248), sucrose percent (r = 0.089) and purity percent in juice (r = - 0.144). Internode length showed significant correlations with brix in juice (r = 0.512*), sucrose in juice (r = 0.497*) and millable cane (r = 0.550*) but non-significant correlation with stalk weight (r = 0.466) and purity in juice (r = 0.174). Stalk weight showed non-significant correlation with millable cane (r = - 0.058), brix percent (r = 0.420), sucrose percent (r = 0.266) and purity percent in juice (- 0.045). Millable cane number showed a non-significant correlation with brix percent (r = 0.022), sucrose percent (r = 0.001) and purity percent in juice (r =- 0.091). Brix percent in juice had a strong positive correlation with sucrose percent (r = 0.887**) but no correlation significant with purity percent (r = 0.091). Sucrose had a significant positive correlation with purity in juice (0.500*).

4.4. Path coefficient analysis for cane yield:

The direct and indirect effects of various characters on cane yield are presented in Table 6. Stalk weight showed the highest positive direct effect (0.566) on cane yield followed by stalk length (0.426). Germination (0.271), millable cane (0.204) and brix percent (0.231) showed a moderate positive direct-effect on cane yield but stalk diameter (0.141) and

Table 6. Direct and indirect effect of various characters on cane yield in 16 sugarcane genotypes grown at Jitpur, Nepal in 1999-2000.

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	Total
Germination (X 1)	0.271	0.107	-0.029	0.013	-0.138	-0.033	0.204	-0.023	0.038	-0.027	0.3829
Stalk length (X2)	0.068	0.426	0.059	-0.066	-0.152	0.498	0.075	0.102	-0.049	-0.011	0.9498
Stalk diameter (X3)	-0.056	0.178	0.141	-0.007	-0.077	0.346	-0.046	0.021	-0.016	0.003	0.4874
Internode number (X4)	-0.033	0.267	0.009	-0.11	0.011	0.368	-0.033	0.057	-0.016	-0.012	0.5142
Internode length (X5)	0.138	0.238	0.04	0.004	-0.27	0.264	0.128	0.118	-0.090	0.014	0.5837
Stalk weight (X6)	-0.015	0.375	0.086	-0.068	-0.127	0.566	-0.014	0.097	-0.048	-0.004	0.8480
Millable cane (X7)	0.237	0.137	-0.027	0.015	-0.149	-0.033	0.234	0.005	-0.0001	-0.007	0.4094
Brix in juice (X8)	-0.027	0.187	0.012	-0.026	-0.139	0.238	0.005	0.231	-0.161	0.007	0.3279
Sucrose in juice (X9)	-0.057	0.116	0.012	-0.009	-0.135	0.151	0.0002	0.205	-0.180	0.040	0.1424
Purity in juice (X10)	-0.089	-0.057	0.005	0.015	-0.047	-0.025	-0.021	0.021	-0.091	0.081	-0.2090

Residual value = 0.164

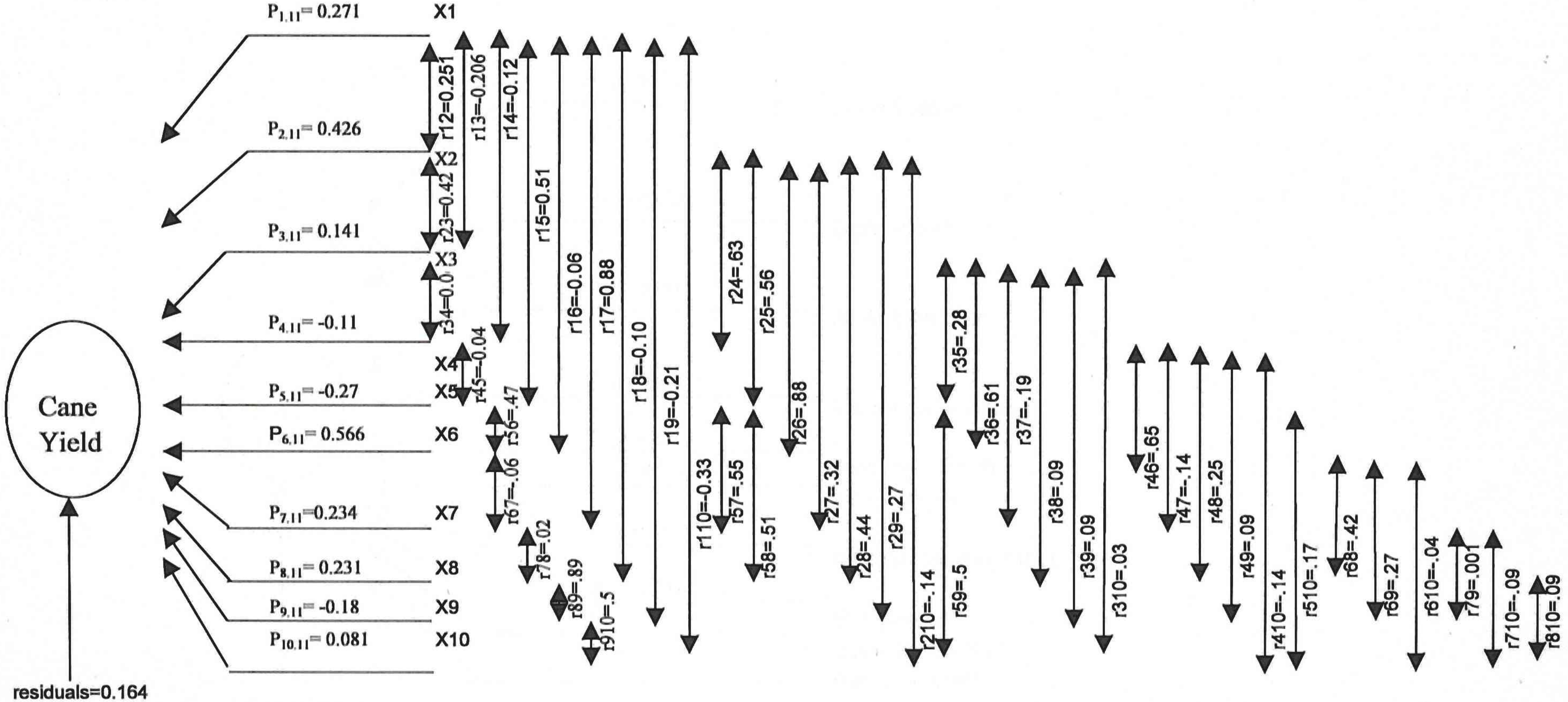

Fig.1. Path diagram showing causal relationship of various characters to sugarcane yield. Doble arrowed lines indicate association between characters as measured by correlation coefficient, and single arrowed lines represent the direct effect as measured by path coefficient influence. X1 = Germination at 45 days after planting. X2 = stalk length. X3 = stalk diameter. X4 = internode number. X5 = internode length. X6 = stalk weight. X7 = millable cane number. X8 = brix% in juice. X9 = sucrose% in juice. X10 = purity% in juice.

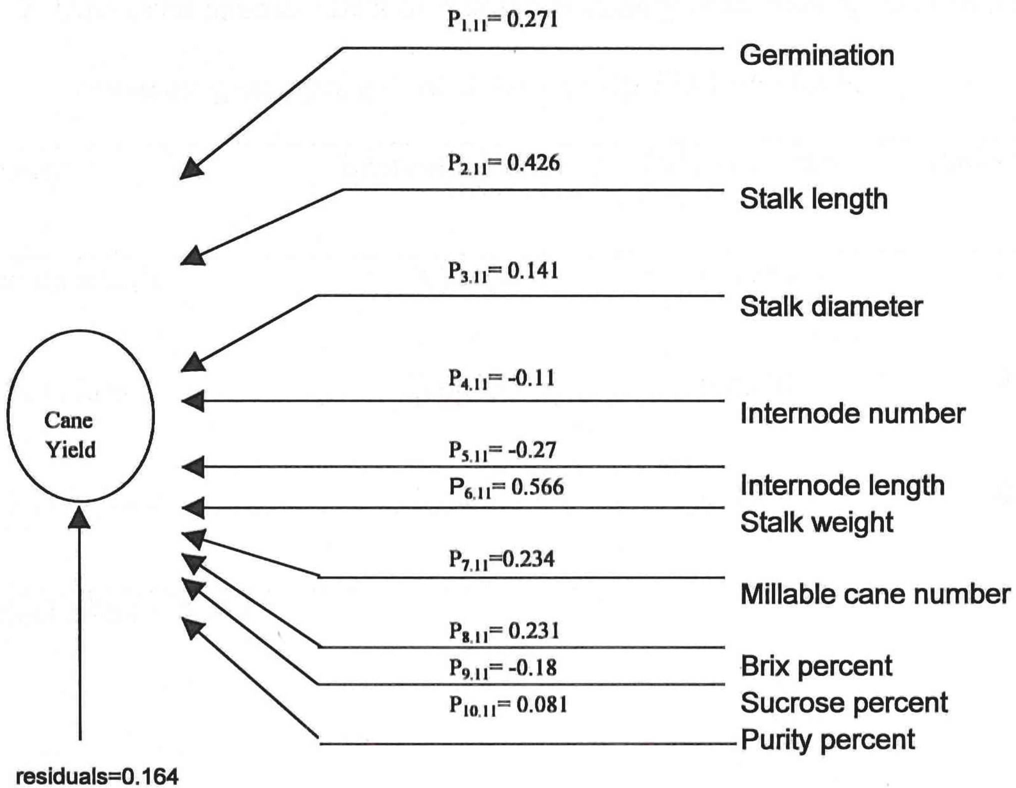

Fig.2. Path diagram showing direct relationship of various characters to sugarcane yield. Single arrowed lines represents the direct path as measured by path coefficient influence.

Table 7. Direct and indirect effect of 3 different quality characters on sucrose percent in juice in 16 sugarcane genotypes grown at Jitpur, Nepal in 1999-2000.

Character	Internode length	Brix % in juice	Purity % in juice	Total
Internode length	-0.0162	0.4398	0.0738	0.4973
Brix % in juice	-0.0083	0.8576	0.0386	0.8878
Purity % in juice	-0.0028	0.0778	0.4252	0.5002

Residual effect = 0.184

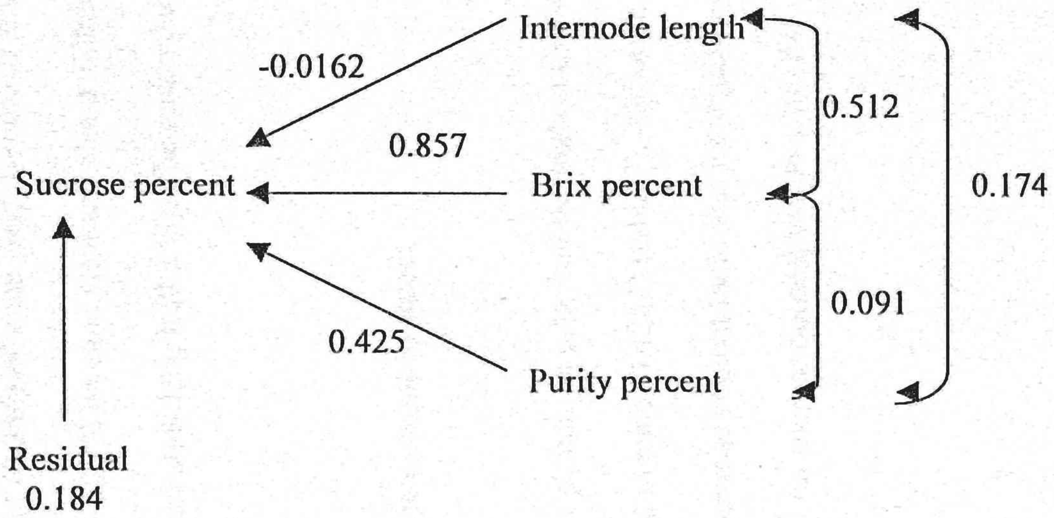

Fig. 3. Path diagram showing causal relationship of various characters to sucrose percent in juice. Doubled arrowed lines indicates association between characters as measured by correlation coefficient, and single arrowed lines represent the direct as measured by path coefficient influence.

purity percent (0.081) had low and negligible positive direct-effect, respectively, on cane yield. Internode number (- 0.110) and sucrose percent (- 0.180) showed low negative direct-effect on cane yield. Internode number had a high positive indirect-effect via stalk weight (0.368) and moderate via stalk length (0.267) on cane yield. Stalk diameter had a high positive indirect-effect via stalk weight (0.346) on cane yield. Internode length showed negative moderate direct-effect (- 0.270) on cane yield and also a indirect moderate effect via stalk weight (0.268) and stalk length (0.238). The residual effect was low (0.164).

4.5. Path co-efficient analysis for sucrose percent in juice:

Path coefficient analysis revealed that brix percent in juice had the highest direct positive effect (0.8576) followed by purity percent in juice (0.4252) (table 7). Although internode length had a significant correlation with sucrose content there was its negligible negative direct effect (- 0.016). The residual effect on sucrose content was low (0.184).

5. DISCUSSION

5.1. Analysis of variance:

There were significant differences among the genotypes for all characters reported here in, except for purity percent in juice. This can be attributed to the fact that these clones were derived from parents having different genetic and geographical backgrounds. So far as purity in juice is concerned, the clones did not differ significantly, because of the fact that the genotypes of different genetic constitution fully matured during February.

Since, the clones have significant differences among themselves for different morphological and quality characters with one exception, it can be expected that these clones, if intermated among themselves, could produce seedlings with combinations of desirable characters.

For sugarcane, yield and juice quality characters are equally important. In present investigation BO. 128, a mid maturing genotype, showed significantly higher yield followed by CoSe. 95422 and CoSe. 92430, which did not differ significantly from one another. Similar results were obtained in an evaluation trial (spring planting) conducted at SRP, Jeetpur during 1997/98 where BO 128 had shown the highest yield of 75.66 t ha^{-1}, with 19.64% sucrose in juice (SRP, Jitpur 1997/98).

5.2. Heritability:

Heritability can give true picture of heritable portion of variability. High heritability estimates was recorded for stalk weight (88.2), stalk length (87.4), internode length (83.8), cane yield (82.6), millable cane (80.8), germination (77.3) and stalk diameter (71.0). This suggested that selection for these traits would be effective. Nair et al. (1980) and Singh et al. (1994) reported high heritability estimates for stalk weight. Like wise high heritability estimates for stalk length was also reported by many workers (Singh et al., 1994; Ghosh and Singh, 1996; Singh and Sangwan, 1980; Kumar 1997 and Kamat, 2000). Singh and Sangwan (1980), Ghosh and Singh (1996), Kumar (1997), Balasundarum and Bhagyalakshmi (1978) and Kumar (1999) reported high heritability estimates for cane yield. However, moderate values for heritability estimates were found for internode number (61.8). Singh and Sangwan (1980) reported moderate heritability estimates for stalk diameter. For juice quality characters low heritability was recorded with brix percent, sucrose percent and purity percent in juice. Heritability estimates for a character with low heritability, say less than 0.4, selection may be considerably difficult or virtually impractical due to the masking effect of the environment on genotypic effects (Singh, 1993). Sahi et al. (1977) and Kumar (1997) also reported low heritability estimates for juice quality characters.

Stalk weight, stalk length, internode length, cane yield and millable cane number would be helpful in making selection of superior genotypes on the basis of phenotypic performance.

5.3. Correlation coefficient:

The cane yield was positively and highly significant correlation with stalk length (r = 0.950**) and stalk weight (r = 0.848**). There was significant positive correlation with cane yield and internode number (r = 0.514*) and with internode length (r = 0.583*). A positive value of '*r*' shows that the changes of two variables are in the same direction, i.e. high values of one variable are associated with high values of other and vice versa. Similar results were obtained by Rangnathan and Narasimhan (1967), Brown et al. (1969), Bathla (1978), Yadava and Sharma (1978), Punia et al. (1983), Verma et al. (1988), Ghosh (1991), Gravois (1991), Patel (1993) and Chaudhary and Singh (1994). There was a non-significant positive correlation of cane yield with stalk diameter, millable cane, germination, brix, sucrose and purity in juice. For stalk diameter non-significant correlation might be due to non-availability of added nutrients to the crop especially phosphorus which highly influences the cane diameter (Lakshmikanthan, 1973). In other words, this is true in the sense that the diameter of the test genotypes was too small. Among juice quality characters there was significant positive correlation between brix and sucrose percent. Nagaswararao and Ethirajan (1984) and Ghose (1991) found significant positive correlation between brix and sucrose. It is obvious from the above discussion that stalk length, stalk weight, internode number and internode length can be associated together in a positive direction towards an ultimate aim of developing high yielding sugarcane clone. Among morphological characters, internode length had a significant positive correlation with sucrose in juice. For millable cane number non-significant correlation might be due to more competition for natural resources as light, water, nutrients etc. low yield of cane was obtained.

5.4. Path coefficient analysis for cane yield:

The path coefficient analysis unfolds whether the association of cane yield with its component characters is due to the direct effects of component characters on cane yield or is a consequence of its indirect effect via some other traits. Therefore, in order to improve cane yield, effective selection can be practiced for the characters having high direct effects and for the characters through which indirect effects are mainly exerted on cane yield. In the present investigation, the highest positive direct effect on cane yield was exerted by stalk weight (0.566) followed by stalk length. (0.426). This implies that selection of sugarcane genotypes on the basis of stalk weight and stalk length would be beneficial for increasing sugarcane yield. Punia et al. (1983), Reddy and Reddi (1986) and Hooda et al. (1988) reported that single cane weight was the most important component of cane yield. Hooda et al. (1979) observed that single cane weight was the main character contributing directly to yield followed by plant height and brix value. Path coefficient analysis by Kang et al. (1983) indicated that plant height was important for cane yield. Patel et al. (1993)

concluded that commercial cane sugar was the most important component of cane sugar productivity, which showed the largest direct positive effect. Chaudhary and Singh (1994) found that individual cane weight and millable cane number the main characters contributing directly to yield. Internode number and internode length showed significant correlation with cane yield. But their direct effects on cane yield were low and moderate negative. Significant correlation was due to indirect effect of stalk weight and stalk length. Residual effect indicated that there was a few more characters responsible for yield improvement which were not included in the present study.

5.5. Path coefficient analysis for sucrose percent:

Internode length, brix in juice and purity in juice showed a positive relationship with sucrose percent but the highest positive direct effect was of brix in juice followed by purity in juice. The internode distance had negative direct effect on sucrose in juice. Gravois et al. (1991) observed that purity was the main factor for increasing sucrose content. Nagesware and Ethirajan (1984) also reported that brix at 12 month had a high positive direct effect on sucrose percent.

6. SUMMARY

This study involving 16 sugarcane genotypes was conducted to: (i) To estimate the heritability of different characters. (ii) Find out the association of different traits among themselves including sugarcane yield (iii) Know the direct and indirect effects of different characters towards cane yield and sucrose content through path coefficient analysis. The sixteen clones were planted in a randomized block design with four replications at SRP, Jeetpur, Bara. Characters evaluated were germination at 45 days, stalk length, stalk diameter, internode number, internode length, stalk weight, millable cane number, cane yield, brix percent, sucrose percent and purity percent in juice.

There were significant genotypic differences for all the characters except purity percent in juice. The genotypes B0.128 gave the highest cane yield and also produced the highest brix percent and sucrose percent in juice.

The high heritability estimates were associated with stalk weight, stalk length, internode length, cane yield, millable cane, germination at 45 days and stalk diameter. But internode number had moderate heritability estimates. For juice quality characters, lower heritability was found.

Among morphological characters, cane yield was significantly positively correlated with stalk length and stalk weight. Significant positive correlation of cane yield with internode

number and internode length. There was non-significant positive correlation with stalk diameter, millable cane, germination at 45 days, brix and sucrose in juice. Germination at 45 days was positively correlated with millable cane number. Stalk length showed a was highly significant positive correlation with internode length. Internode length had a significant positive correlation with brix in juice and sucrose in juice.

Path coefficient analysis of cane yield with its component characters revealed high direct positive effects of stalk weight and stalk length. Germination at 45 days, millable cane and brix in juice were also important characters due to their moderate positive direct effect towards cane yield.

Path coefficient analysis of sucrose in juice revealed that brix in juice had a high positive direct effect followed by purity in juice while internode length had a negative and low direct effect on it.

7. CONCLUSIONS

1.The genotypes should be selected on the basis of stalk weight and stalk length as well as characters, germination at 45 days after planting and millable cane number for higher sugarcane yield.

2. For higher sucrose percent of juice emphasis should be given on brix and purity in juice while making the better clones in sugarcane.

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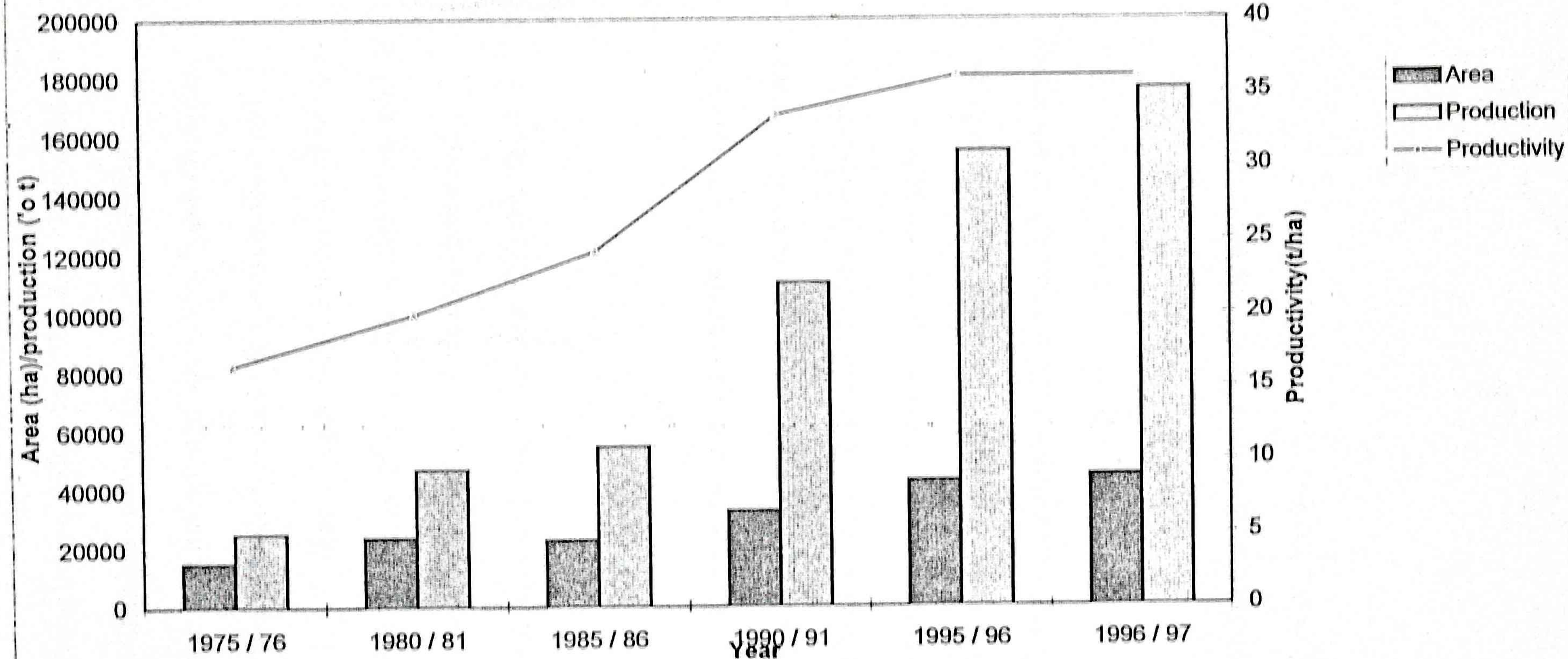
Appendix A. Area, production and productivity of sugarcane in Nepal from 1975-1996.



Source: Sugarcane Research Program, Jitpur 1998.

BIOGRAPHICAL SKETCH

The author was born on Jan. 2, 1955, at Inerwa, Sirha, Nepal. He is the eldest of the five children born to the Late Pashupati Chaudhary and his wife Budhiari Chaudhary.
He received his high school education from Rameshwar High School, Rajanagar, Bihar, India. In 1972 he passed his Bihar Board Examination in the first division. He joined Intermediate of Science (I. Sc.) at B. S. College, Dinapur, Bihar. He received an Indian Merit Scholarship and passed I. Sc. in 1974 in the 2nd division. He obtained a Bachelor of Science in Agriculture (B.Sc.Ag.) degree from Tribhuvan University, Institute of Agriculture and Animal Science (IAAS), Central campus, Rampur, Chitwan, Nepal in 1980.

After his graduation he started his professional career at the Agriculture Centre, Khajura, Nepalgunj as an Assistant Pathologist in 1980. In 1982, he was transferred to Sugarcane Research Programme, Jitpur as an Assistant Agronomist. In 1983, he was transferred to the District Agriculture Office, Birgunj, Parsa as a Production Officer and again transferred to Sugarcane Research Programme, Jitppur. The author was involved in the publication of booklets Khuti Ukhu Bali Byabasthapan and Ukhu Sanga Anterbali written in Nepali.

He is happily married to Triveni Kumari Chaudhary with whom he is blessed with a daughter Padma and two sons Rajeev and Rabins.