5. DISCUSSION

5.1. Introduction

Domestic production of chilli in Malaysia has not kept pace with demand especially in the last few years. This is evident by the increase in imports of this commodity into the country (MOT 1988-1995). The sudden economic recession of 1997/98 together with the high price of fresh chilli have created fresh interests in this commodity. The increase in the local production of chilli would reduce the increasing import cost, which is amounting to RM56 million in 1995. One possible way to increase local production is through increasing planted area with superior varieties. Being a less competitive crop, it is likely that chilli cultivation is allocated in marginal lands. Being a shallow rooted crop, chilli has an advantage over more important deep rooting cash crops, for cultivation of chilli on such soil requires less soil amelioration.

Both fresh and dried chilli are used for raw materials in chilli sauce industry, however, more of the latter type is preferred for convenient reason. The success of the dry chilli production depends on solving the existing production problems. The existing high biological variation due to natural outcrossing occurring in chilli (Engle 1993; Bosland 1993b; Kanwar 1995) offers great scope for genetic improvement. However, the polygenic control of yield coupled with the environmental effects which often cause variability and instability in yields and other agronomic and quality determinant traits makes selection rather difficult.

Characters like maturity and plant stature would provide indirect effects on the spread of the diseases. Early maturity for instance, would enable the crop to be harvested before the onset of the diseases (Melor 1995). Plant stature (architecture)
affects micro-environment, which in turn would influence the spread of the fungal diseases. Plant stature also determines plant density. Plant height and growth habit influences the necessity of staking and the ease of harvesting. Equally important are parameters such as conversion rate from fresh to dry chilli, and ease of drying either at pre or at post harvest are of major importance for processing chilli. They contribute directly to processing cost and therefore are worthy of consideration.

The information on how the general features such as soil types, climate and relative humidity, and how the unpredictable fluctuation in weather, such as amount and distribution of rainfall and temperature that can be taken into consideration in fixing planting time, planting density and agronomic practices could affect crop performance.

The information on genotype x environment interaction helps in deciding whether to embark for specific adaptability to particular environments or general adaptability.

5.2. Genetic x environment studies

5.2.1 Yield and yield components

Yield is the most important agronomic character, which is polygenically controlled and complex in nature. It is contributed mainly by yield components or other yield contributing factors. In chilli crop, the yield components include fruit number per plant and mean fruit weight. Plant height has been found to contribute to yield but indirectly. Genes controlling yield were often affected indirectly through the yield components. Yield was reported to be highly affected by various components of
environments. This complexity was further magnified by the interaction of the inherent cultivar differences and the environmental effects.

The current multilocational trials illustrated the very significant differences in genotype and environment. The environmental differences were contributed mainly by differences in rainfall distribution during the two planting-seasons within location, and very significant interaction effect between planting-season and location, together they made up 71% of the total yield variance. Provision of suitable growing conditions such as the suitable soil type, climatic zoning or temperature ensure maximum yield performance. Genotype x environment interactions were also noted in yield and yield components. The genotype x environment (G x E) interaction effects contributed about 9% of the total variance in yield. When the G x E component was subdivided into three components, namely, genotype x planting-season (g x s), genotype x location (g x l) and residual genotype x location x planting-season (g x l x s), the significant genotype x environment interaction detected was mainly due to both genotype x location and genotype x location x season effect. This indicates that some varieties are location specific and they could be planted any time of the year since no interaction between genotype and planting-season was recorded. The existence of both G x E and high environmental variance indicate the possibility of yield improvement by manipulation of environmental variables and thus requires varieties which are responsive to change in environment.

Environmental differences such as soil type, rainfall and temperature have been found to influence yield. Mineral environment recorded yield significantly higher than any other soil type. Of the mineral soil environment, the highest yield was recorded
in Cameron Highlands. Possibly, the cooler temperature has given an edge to Cameron Highlands compared to other mineral environments. As expected marginal soil environments namely Kundang, Jalan Kebun and Kuala Linggi, on tin tailing, developed peat and acid sulphate respectively, recorded lower yields than those produced on mineral soils. It is interesting to note that the ranking of the location remains the same despite the significant interaction effect between planting-season and location shown in ANOVA. This is indicative of the location effect is more significant than the planting-season effect.

Mineral soil environments (Cameron Highlands, Gajah Mati and Telong) are rich in inherent nutrients, which are easily available than that of marginal soils (Kundang, Jalan Kebun and Kuala Linggi) which are naturally poor in nutrients. While the nutrients in peat and acid sulphate soils normally are not easily available because of the acidic nature of these soils. With proper soil amendments and the recommended fertilizer application (Vimala and Zahara 1992) the yields produced in marginal soil areas were comparable to that of mineral soil environment. This suggests the potential of chilli cultivation in the marginal lands. Nevertheless, further fertilizer study for these marginal soils is still necessary. It has been observed that all the varieties recorded the maximum mean fruit weight in Cameron Highlands. This was an indicative of the favourable effect of the lower temperature and high relative humidity on fruit size, which in turn had led to considerable higher yield in Cameron Highlands, compared to the other mineral soil environments. Though, similar mean fruit weight was obtained in second crop, the heavy rainfall however, had caused considerable reduction in yield due to high incidence of flower abortion resulted in lower fruit set.
Further loss in second planting-season was probably due to high incidence of anthracnose. High possibility also that the heavy rainfall in the second planting-season had lowered the soil temperature to lower than 20 °C at which the development of plant stops (Somos 1984). Under such circumstances, the temperature of the soil water that exerted the effect rather than the water itself (Ugarchinski 1964). Similarly, the lower fruit set and the high anthracnose damage as a result of heavy rainfall could have contributed to yield reduction in Kundang second crop. Being a tin tailing area with high rate of water loss, cooling effect of water due to heavy rain may not be felt.

Too little rainfall also appeared to cause yield reduction. Considerable yield reduction shown in the first crop in Bertam, the second crop in Gajah Mati and the first crop in Jalan Kebun, coincides with the low monthly rainfall of 99 cm, 150 cm (during flowering) and 165 cm received by these locations, respectively. The deficient water supply and the high temperature could have caused general reduction in both vegetative and generative growth of the crop. Reduction in fruit number could be the likely cause of the yield reduction observed in all the varieties. The severity of the effect varies with varieties. This happened because some varieties were more tolerance to high temperature or water stress than others (Takagaki 1993; Takagaki et al. 1993; Techawongstein et al. 1992).

As for mean fruit weight, the genotypic variance is bigger (39%) than the environmental variance (27%). There were significant interactions between genotype and environment (15% of the total variance). The genotype means across the environment can be grouped into several groups: big fruit (>7.0 g), medium (5.5-6.9 g), fairly small fruit 3.5-5.4 g and very small cili padi like (<3.0g). It is appropriate
that the biggest fruits of about 7.5 g and 7.2 g each were produced by the highest yielding varieties Ch291P(V1) and Ch389 (V58) respectively. Both plantings in Cameron Highlands recorded the highest environmental average of more than 7 g per fruit. In Cameron Highlands, all the varieties exhibited significant increase in mean fruit weight, with majority of them producing the maximum size. Obviously the cooler temperature of Cameron Highlands ranging between 13.5 °C to 26 °C together with the high relative humidity (Baer and Smeets 1978) seemed to provide the most favourable temperature for fruit size. Rainfall distribution however, showed no obvious effect on mean fruit weight. No significant difference in means fruit weight was seen between planting- seasons in locations, such as Bertam and Jalan Kebun, where very different rainfall distributions during each planting-season were recorded. Crops in Linggi and Jalan Kebun on the other hand, produced small size fruits. The acidic environment of Kuala Linggi and Jalan Kebun could have suppressive effect on fruit size.

Fruit number reportedly was influenced both by genetic and environmental factor and this was confirmed by the current study recording significant differences between genotypes, between planting-season within locations and between locations. Genotypic means for fruit number ranging from 59-253 fruits/plant were recorded, with the biggest fruit variety recording the least fruit number per plant, and the smallest fruit genotype showing the highest fruit number, illustrating a simple negative relationship between size and number of fruits. Small fruit genotypes and medium size fruit groups showed considerable high fruit number of between 115-160 fruits per plants. Location wise, there was no definite pattern observed indicating genotype
effect was less than environmental effect on this parameter. Cooler temperature showed no obvious effect but rainfall distribution exerted significant effect on number of fruits/plant.

Plant height contributed indirectly to yield, mainly through increase in number of branches and hence fruit number. The tallest variety is Ch 252-C-P(V49) and shortest was Ch286(V31). Accession Ch234-14 (V46) and Ch 389(V58) were of average height of about 69 cm. The current result tends to agree with Todorov (1992) who observed environment has greater influence than genotype in plant height. The effect of environment was evident by differences in the mean plant height recorded. Like in fruit number, cooler temperature in Cameron Highlands did not appear to favour plant height. The general trend showed mineral soil is better than any other environments with the highest plant height recorded by crop in Gajah Mati in Zone 1. The shortest plants were observed in acid sulphate area in Kuala Linggi, which is in Zone 2. It appears that soil type exerts greater effect than temperature. Soil water also appears to affect plant height. Optimum water supply appears to provide favourable environment while drought and surplus rainfall appear to provide suppressive effect on plant height. This is in agreement with Gracza (1978) and Somos (1984) who observed shoot grew to maximum at optimum water while either too abundant water supply or deficit of water reduced vegetative growth.

Acceptable plant height under Malaysian condition is 60 cm (Melor 1995). Very short or very tall varieties are not desirable. Plant height or rather plant stature affects micro-environment. Very short plant of type '1' (Appendix I) reduces ventilation, which encouraged high incidence of fungal diseases which in turn causes
considerable loss in yields. Furthermore, very short plant may also cause harvesting problem, especially if harvesting is conducted manually. Very tall plants on the other hand, cause lodging problem especially those planted on peaty environment. Staking is needed to prevent lodging and staking incurs extra production cost. Plant height or plant stature also indirectly influences the yield/unit area of the crop through the planting distance. The bigger the plants, the wider is the planting distance and thus the lower is the plant density. Determinate growth habit as in type '5' (Appendix I) facilitates mechanical harvesting, thus, considered desirable character especially in large scale production.

In selection for plant height, it is worthwhile to remember that the inheritance of plant height is incomplete dominance and controlled by 2-3 genes with the environment having stronger influence than genetic factor (Todorov 1992). In addition there exists genotype x environment interaction acting on plant height indicating the possibility of specific variety for specific environment, which will be discussed under stability.

It is possible for yield improvement to be made through manipulation of agronomically controllable environmental variable. Having medium heritability (75-89%), it is suggested that improvement in yield be conducted in high productivity environments (Frey 1964). Such environment would give the test genotypes a chance to express their maximum potential for yield, thereby tending to increase heritability. Alternatively, yield can be improved through indirect selection of yield contributing factors namely fruit size, fruit number and even plant height, which are more heritable than yields itself, with respective heritability of 96%, 91% and 90%.
5.2.2 Other agronomic characters

Agronomic characters such as maturity or days to harvest showed no direct relationship with yield. However, their influence on the incidence of some diseases might have indirect bearing on the yield. Early maturity variety has greater opportunity to escape disease than the late maturity varieties. In this context early maturity varieties are preferable. In days to harvest, environmental effect appeared to contribute the greatest effects. The cooler temperature and high relative humidity (Baer and Smeets 1978) of Cameron Highlands had delayed the maturity period of chilli crop tremendously. Delay harvest is not desirable because it stretches cropping period, therefore incurring higher management cost.

Conversion rate determines the amount of raw material required to produce dry chilli. It is desirable to have varieties with high conversion rate. Greater genotypic variance relative to environmental variance was observed. There were significant differences between genotypes and between locations but no interaction between season and variety was noted. Mean coefficient of variance of 18.1% was recorded. With genotypic means ranging between 14.9-24.0% and average mean of 19.24%, the present studies showed that all tested genotypes meet the break-even point (15.0%) for processing purposes. Conversion rate is no longer a limiting factor in dry chilli production locally.

Ease of drying contributes to the cost of the production. It is reflected by number of days taken to dry (DTD) which has shown direct positive association (r=0.7) with thickness of the mesocarp (Table 4.3). Days to dry affects production cost. The shorter is the DTD the less is the production cost hence the more desirable
are the genotypes. DTD composed of genetic and environmental components. This was evident by the existence of significant varietal differences and significant differences between locations, planting-season and environments. DTD recorded small coefficient of variance of 18.7% and mean of 15.4 days and exhibited narrow range of environmental means (9.7-13.8 days) and even narrower genotypic means (14-16 days) were observed under local environments (Table 4. 14). Exotic varieties showed the least number of days to dry, which was about 14 days. These varieties included India Sanam, Purple chilli and Ch291 (Korean chilli). Local genotypes such as Kulai, MC4, Ch387 (V56), MC11 and Ch389(V58) on the other hand required 16 days or more to dry.

Location wise, the least environmental means for days to dry of 9.7, 11.8 and 13.8 days were exhibited by Bertam first and second planting-season and Linggi first planting-season, respectively. Locations in Agriculture drought Zone 2 recorded values of less than 14 days. While locations in Zone 4 recorded the longest time taken to dry. This is expected because there is no drought period in Zone 4. Most probably the lower relative humidity in Zone 2 helps to hasten the drying process. There is slight interaction between location/planting-season and variety and there was no significant interaction between season and variety detected. It appears that a part from genetic factor, drying time follows the drought regime. Of the tested areas, Zone 2 seems to be the most suitable area for dry chilli production. The least drying time recorded for natural drying under local environment was between 10-12 days. With the present price of fresh chilli however, this drying time is considered uneconomical to embark in dry chilli production. Further research on drying method to ensure further reduction in drying time and more cost effective is necessary.
5.2.3. *Quality determining characters*

The important quality determining characters in chilli include conversion rates, colour of product, colour retention reflected by bleaching, ease of drying and pungency. Similar to yields, there were significant differences between genotypes and between locations but no interaction between season and variety.

Colour is an important factor that determines the quality of the chilli. The more intense red is the product; the better is the quality. Colour is denoted by the light transmission. The higher the light transmission the lighter is the colour of the chilli. Colour of chilli product is actually the outcome of the colour retention after drying which is indirectly influenced by percentage of bleaching. The higher the percentage of bleaching the less red the product becomes. Consequently both colour and percentage of bleaching would be considered together. There were significant differences between genotypes and between locations but no interaction between season and variety was noted for light transmission. Mean coefficient of variance of 34.72% and overall mean recorded was 7.6% for light transmission. Apart from genetic, colour is affected directly by handling method. Relative humidity may influence percentage of bleaching which indirectly influence the colour.

Percentage of bleaching (Table 4.16), showed highly significant differences between genotypes but there were only a slight interaction between variety and location, and variety x location x planting-season and there was no interaction between planting-season and variety. Mean coefficient of variance was 41.4% while the overall mean recorded was 35.7% for percentage of bleaching. Wide range of values was noted for percentage of bleaching. The genotype with the lowest
percentage of bleaching was Ch 252-C-P (16.0%) and the highest percentage of bleaching was exhibited by genotypes Ch291-P which happened to be the smallest and the biggest fruit varieties, respectively. There were significant differences between locations. Bertam planting - season 2 and Jalan Kebun planting- season 1 exhibited the lowest percentage of bleaching of 17.3% followed by Gajah Mati season 2 and Linggi season1. There was no difference between Kundang 2 and Linggi 2. Cameron Highlands and Telong exhibited among the highest in percentage of bleaching. This coincides with distribution of relative humidity (Table 4.4). Higher percentage of bleaching persists in areas with higher relative humidity. Percentage of bleaching influenced colour retaining ability and hence colour. Thus, colour is also indirectly affected by environment specifically relative humidity. Selection is, therefore, not an effective approach to improve percentage of bleaching and colour unless the selection is conducted in the most favourable environment with low relative humidity and proper handling technique.

Another important quality determining factor in chilli is the pungency level, which is important both in food and pharmaceutical industries. Pungency is determined by an alkaloid known as capsaicin. The higher the capsaicin present the more pungent is the product and the better is the grade. The present study showed that environmental variance constitutes about 70% of the total variance, while genotypic variance constitutes 6% of the total variance. This agrees with the earlier finding of Levy et al. (1989) who observed that capsaicin was greatly influenced by environments and genetics. The environmental variance constitutes mainly by location x planting-season effect and location. Combination of mineral environment and drought during growing season appears to provide the most favourable environment
for capsaicin formation. This is illustrated by the high capsaicin recorded in those sites located in northern region. Cameron Highlands having the cooler temperature exhibited the lowest mean values while Telong with heavy rainfall during growing season also appears to exhibit low capsaicin values. Mineral environment with high temperature of 30 °C or higher, and less water during growing season appear to favour the formation of capsaicin (Somos 1984). On the other hand, cooler temperature such as of Cameron Highlands and surplus soil water, appear to illustrate suppressive effect on capsaicin. The existence of environmental variance, varieties and environment interaction constituting about 39%, 4% and 14% respectively of the total variance in pungency complicates and makes selection for this character rather difficult. The high environmental component suggests possibility of improving pungency level through provision of most favourable environment.

When dealing with capsaicin, it was noted that capsaicin and fruit size are negatively associated. Consequently selecting for capsaicin tends to decrease fruit size, which in turns may lead to decrease in yield. Because of this, it is suggested that selection for capsaicin be done independent of yield or yield components. To improve capsaicin, Linsey and Bosland (1995) recommended planting of stable varieties such as those in group 1 of Francis and Kennenberg's (1978) namely Ch 252-C-P, Sri Lanka, Ch393 (V61), Xian (V25), Purple Chilli, Ch252-C (V28), and Ch388 (V57). Alternatively, varieties with high capsaicin level but with bi=1 such as Brebes, Ch385 (V54) and Huey Sithon are also considered as desirable varieties for capsaicin. These varieties are responsive to environment change showing specific adaptability for capsaicin content.
5.3. The relative importance of genotype, environmental and genotype-environmental effects

5.3.1. Genotypic effects

All characters studied were influenced or at least in part by genotype. This was illustrated by the existence of variation by ANOVA over macro and microenvironment. All these genetically controlled characters can be improved through selection but genetic advancement depends on the magnitude of the genotypic variance. For characters such as mean fruit weight, dry weight and conversion rate, genotypic variance was larger in magnitude than environment variance or the genotype x environment variance, suggesting higher genetic advance could be expected. The high genotypic variance here indicates the presence of sufficient genetic variability in the population used to provide substantial amount for improvement through selection for any of these characters independently. Because of the negative correlation, though not very strong, exists between mean fruit weight and conversion rate has given the impression that it may not be easy to improve mean fruit weight and conversion rate simultaneously. High positive association between mean fruit weight and yield, which is very highly influenced by environment, suggests yield improvement could be achieved through selection for mean fruit weight.

Other characters such as percentage of bleaching, plant height and number of fruits/plant showed considerably large genotypic effect, bigger than genotype x environmental, suggesting that these characters can also be improved through selection with some provision to take care of the non heritable factors.
For yield, capsaicin and days to dry genotypic effect contributed the least as compared to either environmental or G x E effect. Though varietal selection can improve these characters, the greater environmental component implicates the essential of using stable varieties.

5.3.2 **Environment effects**

ANOVA showed that environment contributed the largest effect on yields, fruit number, days to harvest, plant height, days to dry, capsaicin, light transmission, and percentage of bleaching. When characters showed more environmental contribution than genotypic effect, there was possibility of further improvement of these traits through the provision of a more favourable environment.

When the variation among environment effects was expressed in terms of averages of each location (I) and for each planting-season (s), as well as residual location x planting-season (Ixs) interaction, it appears that for yield, Ixs effect contributes the greatest effect. While for mean fruit weight, days to harvest and plant height, location exerts the greatest environmental effects. For number of days to dry, location and location x planting-season exerted similar effect. The second order effect, the location x planting-season and location effects contribute the most on number of fruits/plant, dry yield, dry weight, conversion rate, % of bleaching, capsaicin and light transmission (colour of product). First order effect, location exerts more on capsaicin, dry weight and conversion rate and fruit number. While the planting-season exerts more effect on light transmission, % of bleaching and yield.

When partitioning further the environment component in the combined
ANOVA for each trait into location, planting-season, and location x planting-season showed that the strongest contributing factor to environment effect is location and the interaction between location x planting-season for most of the characters namely mean fruit weight, days to harvest, plant height, days to dry, % bleaching, dry weight, conversion rate and capsaicin. Of these, the later four characters were mainly influenced by the interaction of location and planting-season. For yields (both fresh and dry) and number of fruits/plant, the only important effect was interaction of location and planting-season. The planting-season is the only effect on light transmission implying that this character is influenced only by time of planting. The significant first and second order interactions indicate the necessity for multilocalational testing of genotypes to be done over a number of planting and wider range of environments in order to characterise genotypic performance more precisely. All these characters would be enhanced by planting in certain location at certain time of the year.

5.3.3. Genotype and environment interaction

The change in rank order of genotypes in different environments reflected the present of genotype x environment (G x E) interaction which was detected by the analyses of variance (ANOVA). A large interaction of G x E indicates varietal adaptation to specific environment (responsive to environment).

Genotype x environment effects were present in all characters. Relative to the genotypic effect, genotype x environment has greater effects on yield (fresh and dry), capsaicin level, colour of product, number of days taken for fruit to dry and days to
harvest, indicating the instability of these characters. When partitioning the G x E interaction component into three components namely genotype x location (gxl), genotype x planting-season (gxs) and the residual genotype x location x season (gxlxs), significant genotype x environment components detected in yield, number of fruits/plant, mean fruit weight and days to dry were mainly due to genotype x location x planting-season and genotype x location, indicating that the performance of these characters can be enhanced by planting in specific location and time. For capsaicin and conversion rate, the G x E effect is mainly due to significant genotype x location x planting-season and genotype x planting-season.

Genotype x location x planting-season contributes the most effect on bleaching, colour and days to dry. In addition, gxs interaction has also contributed to G x E interaction effect in percentage of bleaching and colour retention. For these characters, selection may not be effective. This is not surprising because percentage of bleaching, colour retention and days taken to dry are also very much influenced by handling method.

Genotype x location exerts the most effect in number of fruits/plant and mean fruit weight indicating the existence of specific adaptability for this character.

5.4 Heritability and genetic coefficient of variation

Heritability is the ratio of genotype expression to phenotypic expression. It shows the effectiveness with which the selection of genotype could be based on the phenotypic performance. While the genotypic coefficient of variation is a measure of genetic variability, existed within a population for a given trait. In other words, whether there is enough inherent variation in a trait for selection to be possible.
Within the population of genotypes studied, the characters which were highly heritable (heritability of more than 0.85) were mean fruit weight, conversion rate, number of fruits/plant, plant height, dry weight and percentage of bleaching. High heritability on fruit number had been reported earlier by Nandpuri et al. (1971) and Jamal Hussain (1977). Of the high heritable characters, only mean fruit weight and number of fruits/plant showed high GCV of more than 25% indicating there was enough genetic variability in the tested populations for making effective and reliable selection. Panse (1957), Arya and Saini (1977) and Singh et al. (1978) also had reported similar findings. Other characters namely plant height, conversion rate, dry weight, percentage of bleaching had medium GCV indicating that although enough genetic variability for selection to be effective, the genetic advance made may be small.

The high genotypic coefficient of variation exhibited by yield indicates enough variability for phenotypic selection. However, its medium heritability suggests that selection should be more effective on yield components rather than on yield \textit{per se}. Other medium heritable characters were capsaicin level, days to dry, days to harvest and light transmission.

In cases where genetic variability is low but reasonably high heritability such as in days to harvest, it is recommended to broaden the gene pool.

5.5 \textbf{Correlation}

In correlation study, one should note that the genetic make up of the population, sample size, the environments and the characters under studied are factors influencing the magnitude and direction of the analysis. For instance, if the population studied is inherently variable for characters under consideration, correlation for these characters
may not be detected. Large sample size can sometimes result in significant relationship when magnitude is low. In cases where the traits respond differently to different environments, they are able to make compensatory or competitive adjustment; the association thus varies from environment to environment.

The current study revealed that yield and quality determinants were low in heritability. They were very much affected by change in environments. Correlation study was necessary to determine the association of these low heritability characters with those of higher heritability characters so that indirect selection could be practised for improving the less heritable traits and also whether the desired characters could be improved simultaneously.

The positive associations between yield and mean fruit weight and fruit number per plant which in turn were negatively correlated to each other observed in preliminary trial persisted in multilocational trials. Yield was positively associated with mean fruit weight in all the environments tested, except Kundang (planting-season 1), a low productivity environment. The relationship between yield and fruit number however, is not consistent. Yield and fruit number showed strong negative association in high yielding environments where the fruit size is maximum. This indicates the compensatory adjustment of these characters with the environments. Nevertheless, both mean fruit weight and number of fruits/plant are good yield contributing factors and therefore are good indicators in yield improvement programme. Thus, selection for these characters might result in yield improvement. Low positive association between yield and plant height was detected in multilocation trials. Other chilli researchers such as Nanpuri et al. (1970), Mutuhukrishnan et al. (1983), Kshrisagar et al. (1983), Dahiya et al. (1991), Khurana et al. (1993) and Ahmed et al. (1997)
also suggested the selection for higher fruit number and taller plant height for yield improvement in chilli.

With characters such as percentage of bleaching and ease of drying, yield showed positive association in preliminary trial where genetic base was larger. However, consistent association was not detected when correlation was based on wider range of environments. Possibly, these traits responded differentially to environmental influences, making compensatory and competitive adjustment resulting in no consistent trend. Such positive correlation however is undesirable since improvement in yield might simultaneously increase day to dry and percentage of bleaching.

Fruit yield on the other hand, showed consistently strong negative association with conversion rate. Both in preliminary trial and multilocalational trials, 12 out of 14 locations recorded negative correlation. This implies that within the range of genotypes under studied, selection for high conversion rate might result in decline in yield.

No association between yield with colour retention, length of fruit stalk or fruit girth was observed, indicating that selection for these characters would not affect yield of chilli.

Yield and capsaicin showed consistently low negative association both in preliminary trial as well as in multilocation trials. This negative association between capsaicin and yield probably was due to the strong negative correlation existed between capsaicin and yield component, fruit size. Of the 14 tested environments, 10 showed variable degree of negative association. The strong association between these two characters were observed in the favourable environments for capsaicin (Table
4.30). Under such circumstances, improvement in yield through selection for fruit size might lower capsaicin content. Similar findings were reported by several researches in various parts of the world (Kvachadze (1973); Khem et al. (1973); Hwang and Lee (1978); Chew (1984); Jiang et al. (1987). They reported that capsaicin level is negatively correlated to fruit size. This relationship indicates any improvement in capsaicin may be at the expense of fruit size. A balanced selection for capsaicin content and fruit size may result in simultaneous improvement of both yield and capsaicin. It is suggested that selection for capsaicin be conducted in favourable environments for capsaicin where the expression of this trait is at the maximum as in the northern region of Malaysia.

Capsaicin showed negative association with percentage of bleaching and light transmission, indicating the possibility of simultaneous improvement in capsaicin and colour retention at the expense of fruit size. Similar finding was reported by Rani (1983) and he advocated balanced selection pressure should be exerted on fruit number and fruit size to improve yield and capsaicin and pigment content, simultaneously. The present study also indicated the association of capsaicin with fruit number, conversion rate, days taken to dry, number of seed per fruit and length of fruit stalk. There existed positive association of conversion rate to fruit stalk and its negative association with number of days for fruit to dry. This was expected since the dry fruit stalk contributes to the weight while time taken to dry is contributed by the moisture in the fruit. It follows, therefore, that selection for conversion rate though may improve the capsaicin level but may decrease ease to dry.

Other yield component, fruit number, when evaluated under wider range of environments, showed some association with capsaicin level and conversion rate,
which in turn showed positive relationship with each other. This suggests that selection for fruit number, capsaicin level and conversion rate can be done simultaneously. Selection for fruit number has no bearing on percentage of bleaching, days taken to dry, number of seed per fruit, length of fruit stalk or fruit girth since these characters had shown no association with fruit number.

It has been established earlier that both fruit size and fruit number are good selection criteria in yield improvement programme because they were more heritable than yield and were positively correlated with yield. When both yield and capsaicin were to be improved simultaneously, there must be a compromise between fruit size and capsaicin. This is because fruit size and capsaicin are negatively correlated to each other. In the present study however, selection for bigger size fruit may not affect the level of capsaicin because the population studied showed acceptable level of capsaicin. Being positively correlated to both yield and capsaicin, selection for fruit number to improve yield may not suppress capsaicin level. On the other hand, its negative association with the other yield component (fruit size) may complicate matters. A balance selection between fruit size and fruit number may result in improvement both in yield and capsaicin. It is worthwhile to note, Cameron Highlands was most favourable for yield but most unfavourable environment for capsaicin. Cameron Highlands is not a suitable place, northern region (Zone 2 environment) would be a more appropriate for such work since it is favourable place for both yield and capsaicin formation.
5.6. Stability analysis

Relative importance of genotype, environment and G x E effects only help to formulate general strategies in breeding and selection procedures but do not portray the behaviour of individual genotypes to a range of environments. Stability on the other hand, measures the relative performance of the genotypes across the environments. The three different methods used to estimate stability estimates were Francis and Kennenberg's (1978) genotype-clustering, simple regression and non-parametric, the modified rank-sum method (Kang et al. 1991).

The stability is discussed according to characters and genotypes. Here the above average genotypes would be those in Group I of group-clustering of Francis and Kennenberg's (1978) or with $b_i = 0$ (Finlay and Wilkinson 1963) or Type I stability ($b_i < 1$) by Lin et al. (1986) or biological concept of Becker (1981), would be the desired goal. In reality, $b_i$ and yield is often positively correlated (Finlay and Wilkinson 1963; Gray 1982), thus, most desirable genotypes are those with $b_i = 1$ which refer to genotypes with average adaptability/stability which is analogous to Type II stability by Lin et al. (1986), or agronomical concept (Becker 1981) or dynamic (Kang 1991a). While the group with $b_i > 1$ usually has mean below the grand mean or below average adaptability. In cases where variance are heterogeneous such as the present study, regression coefficient $b_i$ 's would have different precision, additional stability parameter is suggested. Another statistic, i.e. deviation from regression, was incorporated as a second stability parameter. A small deviation from regression was considered more stable (Type III stability). Based on this assumption, the most desirable variety in Type III was the one which performed about average in
all environments, i.e. the variety with \( b_r = 1.0 \) and \( (S^2_d)_{1,1} = 0 \) (Eberhart and Russell, 1966).

The genotypes with the lowest sum were regarded as the most desirable. In this system genotypes judged to be unstable were penalised in accordance with the significance level of stability variance and those genotypes judged to be stable maintained their original, numerical mean-rank values. For each characters, varieties were ranked in accordance with preference. The summary of the stability of each genotypes by characters is shown in Table 5.1.

5.6.1. Stability by characters

Yield was shown stability by a total of 17 varieties. Ten varieties showed Group I or stability of Type I (b, approaching zero). These were Ch252-C (V28), MC4, Ch388 (V57), Ch389 (V58), Ch393 (V61), Brebes (V44), MC11 and Kulai. Other Type 1 were Lombok (V15), Hantaka, Taiwan dry chilli (V38) and Ch385 (V54). Stability of Type II by regression method were Purple chilli (V16), Ch257 (V25), Sri Lanka (V31) and Ch387 (V56). When both yield and stability in yield were considered, Modified Rank-Sum method rated Ch291-P (V1), V57, V58, MC11 (V46), MC4, V61, Kulai, V44, Ch254 (V9), V15 and V16. Fewer numbers of varieties were identified with grouping-clustering method compared to those by regression method (Table 5.1). This is because group clustering method did not include marginal cases. This was clearly illustrated by Purple Chilli (V16), though recorded low CV, because of average yield, it was not detected by clustering. While regression, on the other hand, portrayed environmental influence, which was considerably high on yield.
For dry yield, a total of 20 varieties showed stability. Seven varieties showed Type I stability. Of these, six were dry chilli namely Ch252-C (V28), Sri Lanka (V31), Taiwan dry chilli (V38), Ch387 (V56) and two double purpose chilli Ch291 (V32) and MC11. Thirteen varieties showed Type II stability. These were Brebes (V44), Ch393 (V61), Hantaka (V36), Ch388 (V57), Purple (V16), Ch252-C-P (V49), Ch389 (V58), Ch254 (V9), Ch291-P (V1), Kulai, Ch385 (V54), Xian (V25) and Indian Sanam. When yield and stability were considered simultaneously, rank-sum of Kang's (1991a) found variety Lombok (V15) desirable in dry yield.

For fruit number, both regression and grouping methods together identified sixteen stable varieties with only Purple Chilli (Type I stability) common to both. Other Group I or Type I varieties included Sri Lanka (V31), Ch252-C-P (V49), Brebes (V44), Ch252-C (V28), Ch254 (V9) and Ch393 (V61). Other stable varieties of Type II were Huey Sithon (V39), Taiwan dry chilli (V38), Lombok (V15), Ch387 (V56), Hantaka (V36), Xian (V25), Ch388 (V57), MC4 (V63) and MC11 (V46) and all these varieties were not detected by clustering method because they were consistently lower in mean values. Of the stable varieties, V15, V61, V9, V57 were of the big fruited varieties.

For mean fruit weight, a total of 19 varieties showed stability in this parameter. Fifteen varieties showed above average stability of Group I or Type I. Of these highly stable varieties, nine varieties were of good fruit size and they were Ch389 (V58), Ch388 (V57), Ch388 (V61), Ch291-P (V1), Lombok (V15), Ch254 (V9), MC11 (V46), Kulai (V40) and Ch291 (V32) were common to both clustering and regression methods. Other Type I stability (Lin et al. 1986) varieties were Purple
Chilli (V16), Brebes (V44), Ch252-C (V28), Sri Lanka (V31), Ch252-C-P (V49) and Indian Sanam. Type II stability included Huey Sithon (V39), Xian (V25), Hantaka (V36) and Taiwan dry chilli (V38). Except for Xian, all Type II varieties were small fruit varieties. Regression method appeared to portray negative relationship between fruit size and stability.

Plant height, a total of 16 varieties showed stability in this parameter. Thirteen varieties showed Type I stability. Of these, six varieties namely Ch252-C-P (V49), Lombok (V15), Ch254 (V9), Purple Chilli (V16), Ch388 (V57) and Huey Sithon (V39) were jointly identified by clustering and regression methods. Other Type I varieties were Kulai (V40), Ch291-P (V1), Ch389 (V58), Ch393 (V61), Ch291-P (V32), Taiwan dry chilli (V38) and Ch386 (V54). Of the Type I stable varieties, V49, V16, V57 and V39 were tall while V15 and V9 were considerably shorter. Three varieties namely V46 (MC11), Brebes (V44) and Ch387 (V56) were of average mean with average stability (Type II stability). Regression also identified V57 to have the least (S^2_d) of Type III stability in plant height. A very tall plant type might not be a good choice because it might result in lodging hence required staking and thus incurring higher cost. On the other hand, a very short plant type is not desirable because of the harvesting problem.

For days to harvest, fifteen varieties showed stability of which 12 varieties of Types I stability identified by grouping and regression. Ten varieties were common to both grouping and regression methods. These varieties were Ch257 (V25), Ch387 (V56), Ch385 (V54), Brebes (V44), Ch291 (V32), Lombok (V15), Purple Chilli (V16), Ch252-C-P (V49), Ch252-C (V28), Ch388 (V57) and MC11 (V46). The other Type I varieties were Ch389 (V58) and Ch291 (V1). Genotypes with average
performance over all location were Hantaka (V36), Ch254 (V9) and Taiwan dry chilli (V38).

For number of days taken to dry, regression and grouping methods identified a total of 18 varieties with nine varieties common to both. These eight varieties with above average stability (Type I) were Purple Chilli, CK#IT (V38), Ch385 (V54), Ch284-6 (V15), V49, V25, Ch388 (V57) and V56. Other Type I varieties were Ch291-P (V1) and Ch393 (V61). While varieties with Type II stability were Indian Sanam, V31, Brebes (V44), Kulai, V28, V36, V39 and MC11 (V46).

For dry weight, 20 varieties showed stability. A total of 13 varieties showed stability of Type I. Three Type I stable varieties, CK #IT (V38), Brebes (V44) and Hantaka (V36) were common to both regression and grouping, Others seven above average stable varieties in Group I or of Type I stability were Ch 252-C-P (V49), Sri Lanka (V31), Huey Sithon (V39), Ch385 (V54), Ch 252-C (V28), Ch 257 (V25), Ch389 (V58), Ch291-P (V1) and Ch254 (V9). The last three were identified by regression method. The bigger fruit varieties such as Ch 291(V32) and Ch388 (V57) were stable of Type II. Five other varieties with the b=1 (Type II stability) include MC (V46), Lombok (V15), Ch393 (V61), V56 and MC4 (V63). Regression identified Ch387 (V56), Brebes (V44), Ch388 (V57), Ch257(V25), Ch 385(V54),

When weight and stability were considered, variety Purple chilli was considered desirable. Kang's rank-sum (1991) listed V49, V44, V16, V36, V25, V15, V31, V39, V9, V38 and MC11 in descending order of stability.

For conversion rate, a total of 20 varieties were found stable. Of these, 14 varieties of Type I stability, ten varieties namely Ch252-C-P (V49), Xian (V25), Huey
Sithon (V39), Ch252-C (V28), Sri Lanka (V31), Indian Sanam, Ch387 (V56), Brebes (V44), Taiwan dry chilli (V38) and Hantaka (V36) were common to both grouping and regression. And the remaining Type I stability were identified by regression, the varieties were Lombok (V15), MC4 and Ch389 (V58). Seven varieties namely V54, V9, V61, V32, V46, V40 and V58 showed Type II stability.

Regarding percentage of bleaching, 10 varieties were identified to show stability in this parameter. Six varieties showed Type I stability and four varieties showed stability of Type II. Being a negative character, these most desirable varieties were those in Group III which analogous to Type 1 stability of Lin et al. (1986). The six above average stability included varieties Sri Lanka (V31), Brebes (V44), Ch257 (V25) and Ch388 (V57), Ch 252-C-P (V49) and Ch385 (V54). Variety V57 was not detected by regression method. Those of Type II stability were Ch291 (V32), Hantaka (V36), MC11 (V46) and Ch387 (V56). Ranking according to Kang's was as follows V49, V39, V54, V31, V36, India, V28, V44, V56, V25 and MC11.

Light transmission, reflect the colour intensity of the genotypes in question. The higher the light transmission the lighter is the intensity of the colour. The most desirable variety by Grouping technique was Variety India (Group III). Regression method identified genotypes, India and Purple chilli showing average stability over all locations. This was followed by genotypes Ch257 (V25), Ch387 (V56) and Lombok (V15). Most of the varieties were above average stability. The ranking by Rank-sum was as follows V39, V61, V56, V16, V54, V25, V15, India, V36 and V40.

With regards to capsaicin, a total of 18 varieties showed stability of which 12 showed Type I stability. Seven of the Type I varieties namely Ch252-C-P (V49), Sri
Lanka (V31), Ch252-C (V28), Ch291 (V32), Hantaka (V36), Ch393 (V61) and V16 were common to both. Variety Ch388 (V57) identified stable by clustering method. Other Type I stability (Lin et al. 1986) included Ch257 (V25), India Sanam and Lombok (V15). While those with average stability (Type II stability) were Ch291-P (V1) and Ch389 (V58). The remaining Type II stable varieties were Kulai (V40), Taiwan (V38), Huey Sithon (V39), Ch389 (V58), MC11 (V46) and Brebes (V44), which were detected as unstable by group clustering. Varieties V39, V44 together with V54 according to clustering technique showed high capsaicin level in favourable environment. Therefore good performance can be expected from these three genotypes if optimum environment for capsaicin formation is provided.

Characters wise, Eberhart and Russell's method (1966) was able to detect more stable varieties as compared to Francis Kennenberg’s (1978). This is because the Group-clustering technique does not make concessions for genotypes which fall into borderline positions in the quadrants. The regression technique does assume inherent linear relationship between genotypes and environmental effects. Therefore, regression method was more informative of individual genotypic response to environment. Nevertheless, grouping technique is useful if the amount of the variability present in the population is high. Furthermore the technique is simple and clear and illustrative in nature.

5.6.2. Stability of varieties

The stability of varieties varied from method to method (Table 5.1). For instance, summary of the stability by the regression method identified Brebes (V44) as the most
stable variety with stability in 12 characters. With group clustering, Brebes showed stability only in six characters. Next was MC11, which showed stability in 11 characters. Lombok (V15), Xian (V25), Hantaka (V36), Taiwan dry chilli (V38) and Ch387 (V56) with stability in ten characters. Varieties Purple Chilli (V16), V49 and Ch388 (V57) and Ch393 (V61) showed a total of nine characters. Those with stability in eight characters were Ch291-P (V1), Ch252-C (V28), Ch291 (V32), and Ch389 (V58). Varieties with stability in seven characters were Ch254 (V9), Huey Sithon, Kulai and Ch385 (V54). India Sanam (V64) and Sri Lanka (V31) showed stability in six characters while MC4 (V63) showed stability in four characters. The Group-clustering method instead identified Ch252-C-P (V49) as the most stable varieties with stability in 8 characters. This was followed by Brebes (V44), Purple Chilli (V16) and Ch252-C (V28) each, with stability in 6 characters. Next were varieties V31, V25, V38, V39, V57, V36, V61, V46, MC4 and V40

Variety Ch291-P (V1) showed stability in eight characters. Both the regression and group-clustering methods agreed that V1 showed Type I or biological stability in mean fruit weight and days to harvest. V1 also showed stability in bleaching, days to dry, dry weight, plant height. V1 showed Type II stability in capsaicin.

Variety Ch254 (V9) showed stability in six characters with Type I stability in mean fruit weight and other characters namely number of fruits/plant and conversion rate. V9 also showed Type II stability in plant height.

Both regression and group-clustering identified variety Lombok (V15) showing stability in fruit size and plant height. According to the regression method, V15 was the most stable varieties showing stability in nine characters while the cluster
method identified V15 to be stable only in two characters. V15 was also found stable of Type II in dry weight, number of fruits/plant and percentage of bleaching. It was stable in days to dry and capsaicin as well.

Purple Chilli (V16) showed stability of Type II in plant height and capsaicin. V16 also showed stability in days to dry (DTD), light transmission, capsaicin, yield and mean fruit weight by both regression and group-clustering methods. In addition to these, the regression method identified stability in conversion rate, while group clustering identified V16 stable in fruit number with weight and fruit size as border line cases.

Xian (V25) showed stability in a total of 11 characters. The regression method identified Xian (V25) which showed stability Type I for characters such as dry weight, bleaching, light transmission, capsaicin level, yield, fruit number and the days to dry, which was found stable by clustering method. V25 showed Type II stability in mean fruit weight. Although V25 was high yielding, it was unstable for this parameter according to group clustering method.

By regression, Ch252-C (V28) showed stability in capsaicin, solid content and fruit yield. All the three characters were also found stable by the clustering method. In addition, clustering method, indicated V28 which showed stability in fruit number, conversion rate and days-to-dry.

By the regression method variety Sri Lanka (V31) showed stability only in capsaicin. V31 was also stable for fruit number, conversion rate, bleaching and colour according to the clustering method. V31 showed Type II stability in days to dry.
Variety Ch291 (V32) showed stability in fruit size, capsaicin, dry weight, conversion rate, bleaching and Type I stability in plant height. Group-clustering method also identified V32, which showed stability in mean fruit weight and capsaicin.

According to clustering method, Hantaka (V36) showed stability in conversion rate, solid content, days to dry and colour. While the regression method identified V36 to be stable in dry weight, number of fruits/plant, percentage of bleaching and capsaicin level. Dry weight and conversion rate were common in both.

Variety Taiwan dry chilli (V38) showed stability in dry weight and days to dry. In addition, V38 was also found to show stability in fruit size, fruit number and Type I stability in plant height and capsaicin by the regression method. The first two varieties also appeared to be stable in the clustering method.

Huey Sithon (V39) showed stability in dry weight, conversion rate and fruit number. Besides these three, the regression method also found V39 to be stability Type II in capsaicin, fruit size and days-to-dry while the clustering method revealed that V39 to be stability Type I in plant height and colour. The Clustering method found V39 to contain high capsaicin but unstable in this character. Characters fruit size and days-to-dry were not found stable by the clustering method.

The check variety Kulai (V40) showed stability in six varieties which included fruit size, fruit yield by clustering method. Besides mean fruit weight, fresh yield, regression identified V40 to be stable in solid content, bleaching and capsaicin and Type I stability in plant height.

Brebes showed stability in all the 12 characters tested. Both methods identified Brebes (V44) to show stability of Type II in number of fruits/plant. V44 also showed stability in dry weight, conversion rate, yield and bleaching. By the
regression method, V44 showed stability for twelve characters while the group-clustering method identified six characters. The characters that showed stability by the regression method were number of fruits/plant, dry weight, conversion rate, yield, days to dry, bleaching, Type II in plant height and capsaicin. The first five varieties agreed with the clustering method which identified V44 stable also in light transmission but unstable in days to dry which was found to be highly affected by post harvest handling.

The newly released variety, MC11(V46), showed stability in a total of 11 characters. MC11 showed Type I stability in yield, mean fruit weight but border line for capsaicin level. The regression also found MC11 stable in characters mean fruit weight and capsaicin. MC11 also showed Type I stability in yield, fruit number, days to dry and bleaching. MC11 showed Type II stability in conversion rate and plant height.

Another variety which showed stability in 12 characters is Ch 252-C-P (V49). According to the clustering method, Ch 252-C-P (V49) was one of the most stable variety showing stability in plant height, fruit number, conversion rate, dry weight, easily dry, colour and capsaicin content. V49 is high yielding but unstable for yield and fruit size. With the regression method, V49 showed stability (Type II) in plant height, capsaicin, yield, dry weight, conversion rate and bleaching which was not identified by group clustering. Light transmission and number of fruit/plant were not detected as stable by regression.

Variety Ch385 (V54) showed stability in eight characters. V54 showed Type I stability in conversion rate, days to dry, days to harvest, dry weight and percentage of bleaching and Type II stability in yields (fresh and dry) and plant height.
Ch387 (V56) showed stability in nine characters. V56 showed Type II stability in mean fruit weight by both the regression and group-clustering methods. In addition, the regression method identified V56 to be stable in solid content, fruit number and colour and Type I stability in plant height.

Variety Ch388 (V57) which showed stability in 10 characters, showed Type I stability in yield and plant height, bleaching by both methods. Besides these, variety V57, by the clustering method was found to show stability in fruit size, capsaicin and acceptable days to dry. The regression method also identified yield, plant height, bleaching, days to dry, dry weight, colour and fruit number. The regression method did not detect capsaicin, mean fruit weight as stable characters, while clustering did not detect V57 to show stability in number of fruits/plant and dry weight.

Variety V58 with stability in 10 characters, showed stability of Type I in yield, mean fruit weight by both methods. V58 also showed stability in dry weight, capsaicin, and plant height (Type II stability) and number of fruits/plant.

Another variety which showed stability in nine characters was Ch393 (V61). V61 showed Type I stability in mean fruit weight and yield and colour. In addition, the clustering method found V61 to be stable in colour and capsaicin, while V61 showed stability plant height and type II stability in solid content and days to dry and fruit number according to regression.

Variety MC4 (V63) was found stable in yield by both methods. V63 showed Type I stability in dry weight and Type II stability in days to dry, number of fruit and percentage of bleaching.

Both regression and clustering methods found variety India Sanam (V64), stable of Type I in light transmission and dry weight. Variety Indian Sanam also
showed stability in capsaicin and fruit size as well and Type II in days to dry.

Regardless whether stability by character or by variety, in general, the regression method appears to detect more characters compared to clustering method which uses CV to measure within genotype variance as the stability indicator. The regression method is informative of the behaviour of the individual varieties with different environment. It can detect Type II and Type III stability. The clustering method, being an estimate for Type I (Lin et al. 1986) or static stability (Kang 1988) or biological concept (Becker 1981), it does not tell how the genotype behaviour is going to be under different environments. Type I is not dependent on genotypes in the test. The success of Type I depends on broad inferential base. In cases where the variation is not wide enough, there is a chance of having most of them lump in one particular group. The clustering does not make concession for varieties which fall into borderline positions. The ranking of the varieties differed between the methods used.
Table 5.1  Stability estimates of 22 varieties of chilli with respect to yield, yield components and some quality characters

<table>
<thead>
<tr>
<th>Variety code</th>
<th>Yield (g/plant)</th>
<th>Dry weight (g/plant)</th>
<th>Days to harvest</th>
<th>Plant height (cm)</th>
<th>Dry yield</th>
<th>Conversion efficiency (%)</th>
<th>Light transmittance (%)</th>
<th>Capsicum (mg/kg)</th>
<th>No. of days above the threshold stability</th>
<th>Total Score a (Total Score ranking)</th>
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<tbody>
<tr>
<td>CH291 (V1)</td>
<td><strong>+</strong></td>
<td>+*</td>
<td>10</td>
<td>11</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>10</td>
<td>15/14 (2)</td>
</tr>
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<td>CH234 (V9)</td>
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<td>+*</td>
<td>9</td>
<td>8</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>10</td>
<td>15/14 (2)</td>
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<td>7</td>
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<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>10</td>
<td>14 (2)</td>
</tr>
<tr>
<td>Purple (V16)</td>
<td><strong>+</strong></td>
<td>+*</td>
<td>9</td>
<td>8</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>10</td>
<td>15/14 (2)</td>
</tr>
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<td>11</td>
<td>11</td>
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<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
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<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
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<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>10</td>
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<td>11</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
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<td><strong>+</strong></td>
<td><strong>+</strong></td>
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</tr>
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<td>12</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
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</tr>
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<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
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</tr>
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<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>8</td>
<td>13 (2)</td>
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<td>15</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>8</td>
<td>13 (2)</td>
</tr>
<tr>
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<td>16</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>8</td>
<td>13 (2)</td>
</tr>
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<td>17</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>8</td>
<td>13 (2)</td>
</tr>
<tr>
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<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
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<td><strong>+</strong></td>
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<td>20</td>
<td><strong>+</strong></td>
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<td><strong>+</strong></td>
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<td><strong>+</strong></td>
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<td><strong>+</strong></td>
<td><strong>+</strong></td>
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<td>Hara/la (V49)</td>
<td>+*</td>
<td><strong>+</strong></td>
<td>24</td>
<td>24</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>8</td>
<td>13 (2)</td>
</tr>
<tr>
<td>Hara/la (V50)</td>
<td>+*</td>
<td><strong>+</strong></td>
<td>25</td>
<td>25</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>8</td>
<td>13 (2)</td>
</tr>
<tr>
<td>Hara/la (V51)</td>
<td>+*</td>
<td><strong>+</strong></td>
<td>26</td>
<td>26</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>8</td>
<td>13 (2)</td>
</tr>
<tr>
<td>Hara/la (V52)</td>
<td>+*</td>
<td><strong>+</strong></td>
<td>27</td>
<td>27</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>8</td>
<td>13 (2)</td>
</tr>
<tr>
<td>Hara/la (V53)</td>
<td>+*</td>
<td><strong>+</strong></td>
<td>28</td>
<td>28</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>8</td>
<td>13 (2)</td>
</tr>
<tr>
<td>Hara/la (V54)</td>
<td>+*</td>
<td><strong>+</strong></td>
<td>29</td>
<td>29</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>8</td>
<td>13 (2)</td>
</tr>
<tr>
<td>Hara/la (V55)</td>
<td>+*</td>
<td><strong>+</strong></td>
<td>30</td>
<td>30</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>8</td>
<td>13 (2)</td>
</tr>
<tr>
<td>Hara/la (V56)</td>
<td>+*</td>
<td><strong>+</strong></td>
<td>31</td>
<td>31</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>8</td>
<td>13 (2)</td>
</tr>
<tr>
<td>Hara/la (V57)</td>
<td>+*</td>
<td><strong>+</strong></td>
<td>32</td>
<td>32</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>8</td>
<td>13 (2)</td>
</tr>
<tr>
<td>Hara/la (V58)</td>
<td>+*</td>
<td><strong>+</strong></td>
<td>33</td>
<td>33</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>8</td>
<td>13 (2)</td>
</tr>
<tr>
<td>Hara/la (V59)</td>
<td>+*</td>
<td><strong>+</strong></td>
<td>34</td>
<td>34</td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td><strong>+</strong></td>
<td>8</td>
<td>13 (2)</td>
</tr>
</tbody>
</table>

Key: + relatively unstable according to regression methods (*, **) when bi = 1; by approaching zero respectively, grouping technique (S) = @ Sum of rank sum rank of all the characters according to Hung's (1979a)
5.6. 3. Simultaneous selection of varieties

Genotypic mean and stability are often antagonistic in relationship. There were reports on negative correlation between yield and stability of crops including solanaceous crop such as tomato (Gray 1982; Poysa et al. 1986). Facing with low production problem, stable variety with low yield would not be able to solve our current chilli problem. Under such circumstances, genotypic mean takes priority over stability. The varieties were given scores and rankings based on the combination of Francis and Kennenberg (1978) and ranking of Kang (1990) and regression of Eberhart and Russell (1966). The variety with the lowest score is the most favourable.

When yield together with stability in other characters were considered (Table 5.2), Variety Brebes (V44) was identified to top the list with stability in 12 characters, six of which are common to all methods used. Variety V44 is a short variety with above average yield and showed stability of Type I in fresh yield, number of fruits/plant, conversion rate, dry weight, days to harvest, bleaching, mean fruit weight, and of Type II stability in dry yield, days to dry, capsaicin and plant height. It is a scrubby medium height variety with very prolific fruiting habit. It has the quality characteristics required for dry chilli production and also shows potential for large scale planting (Plate 2).

Next on the list were Huey Sithon (V39) with stability in nine characters. Huey Sithon (V39) showed stability of Type I in conversion rate, plant height and light transmission. While stability of Type II was revealed in number of fruits/plant, mean fruit weight, days to dry and capsaicin. A tall plant of types '7' (Appendix I). Huey Sithon produced upright small fruits which look more like cili padi. Though
Huey Sithon does not give the *cili padi* taste but it has high pungency level comparable to *C. Frutescens*. In the light of growing interest in *cili padi*, Huey Sithon which matures earlier than any *C. Frutencens*, can be recommended as interim measure.

The newly released MC11 with stability in 11 characters is third in the list. MC11 is ranked as good yielding variety among the tested varieties, border line for capsaicin with stability of Type I in mean fruit weight, fresh and dry yield, days to harvest and bleaching and showed Type II stability in conversion rate, capsaicin, fruit number, days to dry and light transmission. Fruits of MC11 showed good colour retention on drying and very suitable for processing. MC11 is very prolific variety and showed wide adaptability across environments (Plate 4).

Purple Chilli (V16), a medium size fruited variety with good level of capsaicin and good colouring and acceptable yield showed Type I stability in colouring, days to harvest, conversion rate, days to dry (DTD), plant height and capsaicin. Stability of Type II in both fresh and dry yield. In addition to these, V16 also showed stability in dry weight, fruit number and mean fruit weight as border line cases. Unlike other varieties, Purple Chilli showed very good red colour when matured. It is very suitable for processing. Purple chilli is a tall variety (Plate 3).

The check variety Kulai (V40) showed stability of Type I in mean fruit weight, fresh yield and plant height. Kulai was stable of Type II in dry weight, conversion rate and capsaicin.
Variety Ch385 (V54) showed stability of Type I in dry weight, days to dry, days to harvest plant height and yield. V54 showed Type II stability in dry yield, conversion rate, % of bleaching. Being a small fruit variety, V54 may not be acceptable to local consumers who prefer bigger fruit type.

Variety Ch252-C (V28) is the 7th in overall ranking. It showed stability in eight characters. It showed stability of Type I in capsaicin, solid content, fresh yield, number of fruit, conversion rate and Type II in days to dry. V28 is a tall plant with cili padi like fruits.

This was followed by Ch388 (V58) with stability 11 characters. High yielding V58 was found stable in yield, fruit size by both methods. In addition, V58 is also stable in dry weight, capsaicin, number of fruits/plant and Type II stability for plant height. This prolific variety showed wide adaptability. It has type '5' growth habit indicating the determinate fruiting habit, a character which is an advantage for large scale production.

Variety Lombok, Ch284-6 (V15) showed stability in a total of nine characters. Varieties V15 showed above average (Type I) stability in mean fruit weight and plant height, and Type II stability in light transmission, conversion rate, number of fruit/plant, days to dry, bleaching, capsaicin and yield.

The 10th position in overall ranking is variety Ch388(V57), big fruit and high yielding variety. V57 is of medium height with acceptable days to dry was found to show stability in 11 characters. V57 showed Type I stability in yield and stability of Type II in plant height, mean fruit weight, bleaching, capsaicin and days to dry, dry weight, conversion rate and number of fruits/plant. Similar to V58, this high yielding variety also showed tendency for determinate growth habit (Plate 5)
High yielding, big fruit, Ch393 (V61) was identified to show stability in 9 characters, V61 showed Type I stability in mean fruit weight, yield, colour and capsaicin, while Type II stability was revealed in plant height, solid content and days to dry. V61 has good glossy colour and attractive appearance. V61 also recorded type '5' growth habit indicating V61 also has potential for large scale production.

Variety Taiwan dry chilli (V38) showed solid content and days to dry. In addition, V38 was also found to show stability in fruit size, fruit number and Type I stability in plant height and capsaicin by the regression method.

Though stability in a total of 12 characters, cili padi like variety Ch252-C-P (V49) is 13th in the overall ranking. It is a tall variety of average yield. V49 appears to yield better in the lowlands compared to Cameron Highlands. Variety V49 showed stability in plant height, fruit number, light transmission, capsaicin level, dry weight, conversion rate and bleaching and easily dried. V49 is unstable for mean fruit weight. V49 could be recommended as an interim measure to fulfil the present increasing interest in cili padi.

Variety Sri Lanka (V31) showed stability only in capsaicin and Type II stability in days to dry. Besides capsaicin, V31 was stable for fruit number, conversion rate, bleaching and colour according to the clustering method. Variety Ch291 (V32) showed stability in fruit size, capsaicin, solid content, conversion rate, bleaching and Type I stability in plant height. Group-clustering method also identified V32 to show stability in mean fruit weight and capsaicin.

Three varieties, Ch254 (V9), Ch291 (V1) and Indian Sanam occupy same ranking position. Variety Ch254 (V9) showed stability of Type I in mean fruit weight and Type II stability in plant height, fruit number and dry weight. Variety Ch291 (V1)
showed stability of Type I in mean fruit weight, bleaching, days to dry, dry weight, plant height and Type II stability in capsaicin. Indian Sanam stable of Type I in four characters namely mean fruit weight, light transmission, dry weight and capsaicin, and stability of Type II in days to dry.

Ch387 (V56) showed stability (Type II) in mean fruit weight by both the regression and group-clustering methods. In addition, the regression method identified V56 to be stable in solid content, fruit number and colour and Type I stability in plant height.

Hantaka (V36) showed stability of Type I in conversion rate, dry weight, days to dry and light transmission. Hantaka showed Type II stability in number of fruits/plant, bleaching and capsaicin.

Variety MC4 (V63) was stable of Type I in yield, solid content, fruit number and bleaching and (Type II) in days to dry.

Variety Xian (V25) showed stability in 11 characters with Type I stability in characters such as conversion rate, bleaching, colour, capsaicin and days to dry and Type II stability for yield, mean fruit weight, number of fruits/plant and dry weight. With average means in almost all these characters had reduced the potential of this variety in this country. Being an exotic variety from China, it is not surprising therefore that V25 appeared vigorous and high yielding in cooler region of Cameron Highlands. Xian (V25) showed specific adaptability and best recommended for cultivation at higher elevation.
Table 5.2  Stability estimates for yield (g/plant) and overall scores of 22 hot pepper varieties evaluated at 14 environments

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Mean Square (MS)</th>
<th>Meanrank (X1000) Group *</th>
<th>Coefficient of Variation</th>
<th>Scores for CVs</th>
<th>Regression Coefficient bi ranking</th>
<th>Stability Variance $\delta^2$ (1000)</th>
<th>Kang's R-sum ranking</th>
<th>Score for No. stable chars.</th>
<th>Total R-Sum Rank</th>
<th>Total Over-all Scores ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.Ch291-P(V1)</td>
<td>432.34</td>
<td>37.126</td>
<td>22</td>
<td>4.6</td>
<td>II</td>
<td>4.19***</td>
<td>20</td>
<td>-1.564</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>2.Ch254 (V9)</td>
<td>389.55</td>
<td>31.698</td>
<td>17</td>
<td>4.7</td>
<td>II</td>
<td>1.23***</td>
<td>21</td>
<td>0.392</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>3.Ch284-6 (V15)</td>
<td>405.13</td>
<td>34.163</td>
<td>18</td>
<td>4.6</td>
<td>II</td>
<td>0.52*</td>
<td>2</td>
<td>34.560**</td>
<td>18</td>
<td>10</td>
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<tr>
<td>4.Purple (V16)</td>
<td>363.42</td>
<td>20.401</td>
<td>7</td>
<td>3.9</td>
<td>I</td>
<td>0.85***</td>
<td>13</td>
<td>25.647**</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>5.Ch257 (V25)</td>
<td>315.59</td>
<td>26.131</td>
<td>14</td>
<td>5.1</td>
<td>IV</td>
<td>0.95**</td>
<td>14</td>
<td>55.678**</td>
<td>20</td>
<td>20</td>
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<tr>
<td>6.Ch252-C(V28)</td>
<td>359.4</td>
<td>19.331</td>
<td>6</td>
<td>3.8</td>
<td>I*</td>
<td>0.57*</td>
<td>3</td>
<td>57.032**</td>
<td>21</td>
<td>17</td>
</tr>
<tr>
<td>7.Sri Lanka (V31)</td>
<td>304.83</td>
<td>13.153</td>
<td>2</td>
<td>3.7</td>
<td>II</td>
<td>0.73**</td>
<td>9</td>
<td>32.999**</td>
<td>17</td>
<td>21</td>
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<tr>
<td>8.Ch291 (V32)</td>
<td>390.63</td>
<td>30.119</td>
<td>16</td>
<td>4.4</td>
<td>I</td>
<td>0.65**</td>
<td>6</td>
<td>31.936**</td>
<td>16</td>
<td>14</td>
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<tr>
<td>9.Hantaka (V36)</td>
<td>227.91</td>
<td>13.129</td>
<td>1</td>
<td>5.0</td>
<td>I</td>
<td>0.63*</td>
<td>5</td>
<td>44.004*</td>
<td>19</td>
<td>22</td>
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<tr>
<td>10.Taiwan (V38)</td>
<td>360.9</td>
<td>22.852</td>
<td>12</td>
<td>4.1</td>
<td>I*</td>
<td>0.13</td>
<td>1</td>
<td>62.471**</td>
<td>22</td>
<td>15</td>
</tr>
<tr>
<td>11.Huey Sithong (V39)</td>
<td>323.7</td>
<td>19.328</td>
<td>5</td>
<td>4.2</td>
<td>II</td>
<td>0.84***</td>
<td>12</td>
<td>-1.979</td>
<td>4</td>
<td>13</td>
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<tr>
<td>12.Kulai (V40)</td>
<td>388.3</td>
<td>13.657</td>
<td>3</td>
<td>3.0</td>
<td>I</td>
<td>0.96**</td>
<td>15</td>
<td>3.230</td>
<td>6</td>
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<tr>
<td>13.Brebes (V44)</td>
<td>404.3</td>
<td>21.417</td>
<td>9</td>
<td>3.6</td>
<td>I</td>
<td>1.08**</td>
<td>17</td>
<td>7.329*</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>14.MC11 (V46)</td>
<td>395.6</td>
<td>21.855</td>
<td>10</td>
<td>3.7</td>
<td>I</td>
<td>1.14**</td>
<td>19</td>
<td>1.509</td>
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<td>3</td>
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<tr>
<td>15.Ch252-C-P(V49)</td>
<td>331.2</td>
<td>21.958</td>
<td>11</td>
<td>4.4</td>
<td>I</td>
<td>0.71***</td>
<td>8</td>
<td>14.360**</td>
<td>14</td>
<td>18</td>
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<tr>
<td>16.Ch385 (V54)</td>
<td>239.1</td>
<td>17.811</td>
<td>4</td>
<td>5.5</td>
<td>I</td>
<td>0.62**</td>
<td>4</td>
<td>2.071</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>17.Ch387 (V56)</td>
<td>344.7</td>
<td>23.407</td>
<td>13</td>
<td>4.4</td>
<td>I</td>
<td>0.77**</td>
<td>10</td>
<td>9.460**</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>18.Ch388 (V57)</td>
<td>442.1</td>
<td>35.218</td>
<td>20</td>
<td>4.2</td>
<td>II</td>
<td>1.08***</td>
<td>17</td>
<td>4.644*</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>19.Ch389 (V58)</td>
<td>442.0</td>
<td>28.586</td>
<td>15</td>
<td>3.8</td>
<td>I</td>
<td>1.04***</td>
<td>16</td>
<td>7.900*</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>20.Ch393 (V61)</td>
<td>444.7</td>
<td>36.485</td>
<td>21</td>
<td>4.2</td>
<td>II</td>
<td>0.78**</td>
<td>11</td>
<td>5.099**</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>21.MC4 (V63)</td>
<td>446.3</td>
<td>35.060</td>
<td>19</td>
<td>4.1</td>
<td>I</td>
<td>1.44***</td>
<td>22</td>
<td>10.081**</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>22.Sanam (V64)</td>
<td>273.5</td>
<td>20.998</td>
<td>8</td>
<td>5.2</td>
<td>I</td>
<td>0.70***</td>
<td>7</td>
<td>11.923**</td>
<td>13</td>
<td>18</td>
</tr>
</tbody>
</table>
5.6.4. Delineating suitable areas for chilli production.

The present studies showed the presence of environmental influence on characters tested. The major climatic limitations to chilli production were prolong drought and surplus rainfall. Cooler temperature of Cameron Highlands tends to favour fruit size. Though cooler temperature was expected to favour tallness, this phenomenon was not illustrated in the present study, the varietal effect could have masked the response to the environment. Cool temperature showed no significant effect on fruit number but significant suppressive effect on capsaicin content was recorded. If only yields are considered, the cooler temperature of Cameron Highlands is the most favourable place. However, when both yield and quality character, capsaicin included, higher temperature as in Zone 1 or Zone 2 is more favourable. Based on the climatic requirement mentioned above, the most favourable location for yield is Cameron Highlands, followed by other mineral environments namely Bertam and Gajah Mati and Telong. Mineral soil environment is the most favourable soil type.

While for capsaicin formation, the most favourable environment is Bertam and Gajah Mati, both of which in the northern region where there is distinct dry season. It follows therefore that Northern region would be ideal place for yield as well as capsaicin. Other mineral areas such as Telong and Kundang with too much rainfall of more than 200cm/annum received during cropping season have suppressive effect on capsaicin formation. Mineral soil appears to favour capsaicin formation while acidic nature appears to provide suppressive effect. It can be concluded that mineral environment in the northern region would provide through environment for chilli growing in this region. The studies also indicate that manipulation of agronomic
practices especially fertiliser application for the less fertile soil might improve the yield considerably.

When considering dry chilli production, the influence of environmental conditions especially temperature and humidity on ease of drying and percentage of bleaching which are the key factors in dry chilli production are of very important deciding factors. Almost all regions in Malaysian recorded high RH between 80-93 % (Table 4.3). Under such condition, using modified sun dryer took about two weeks to 18 days for the chilli fruit to properly dry. In Zone 1 and Zone 2 in Gajah Mati and Bertam however, lower R.H of 71-77 % was observed and shorter drying period of 9 days was recorded. Long period of drying of more than two weeks would subject the product to high risk of damage if not high cost. To overcome such problem Rasulpuri (1972) suggested the adoption of artificial dryer to be used in dry chilli production in this country. One draw back of using artificial dryer is the high running cost. This reduces the competitive advantage of dry chilli industry in the country.

5.7. Concluding remark

The primary objective in the production of dry chilli, is improvement in yield with good capsaicin level and colour. In addition, the variety must be of high conversion rate and fast to dry and show some field tolerance to pest and diseases.

As yield and capsaicin were found to be negatively correlated, simultaneous improvement in both of these characters may not be possible. Since mean fruit weight and number of fruits/plant are positively correlated with fresh yield, and both are highly heritable, either one or both are good selection indicators, therefore they can
be used as alternative selection criteria to improve yield.

Improving yield through selection for bigger fruit size however, may reduce one the most important quality attributes of chilli, pungency, due to negative correlation between mean fruit weight and capsaicin content. When both yield and capsaicin to be improved simultaneously, selection for higher fruit number may be a better approach. Further more, selection for fruit number may improve the yield without suppressing another desired character namely conversion rate, since yield is positively correlated with both capsaicin and conversion rate which in turn are positively correlated to each other. The negative association of fruit size and fruit number however, complicates matters, as the increase in one character is at the expense of the other. Nevertheless, a balanced selection pressure on both characters could probably ease this complication. At the same time, it is worthwhile to select for taller plant type, as this would indirectly increase in fruit number and therefore improvement in yield. Very tall plant is not desirable since it may incur extra cost due to lodging problem. Medium size plant also can provide good ventilation thus reduce incidence of fungal disease and therefore the most desirable.

Since all the characters studied were strongly affected by environment, their genotypic response may be masked by environmental influences. Therefore, it is suggested that the selection for any character be based not only on stability of the genotypes but also on the environments. It would be best to conduct the selection in the most suitable environment for the particular character so that the maximum potential of each character is being fully expressed. Besides, this would also reduce the environmental effect masking the genotypic expression.
The present studies also indicated the present of genotype x environment interaction. A significant genotype x environment (G x E) interaction reduces the usefulness of genotype means for identifying superior cultivars (Magari and Kang 1993). Ideal goal for breeders is to get environmentally buffered and high yielding cultivars.

Ideally those varieties with Type I stability with high genotypic mean would be most desirable. However, in reality most of the stable varieties were non-high yielders (Shukla 1972). Therefore varieties of Type II would do equally well. Varieties Ch393 (V61), Ch388 (V57), Ch389 (V58), Brebes (V44), MC11, Kulai (V40), Ch252-C-P (V49), Purple Chilli (V16) and Xian (V25) had been identified to show potential in terms of yield and processing quality.

For dry chilli production, high yielding with above average capsaicin and acceptable conversion rate variety V44, commonly known as Brebes in Indonesia is the most suitable. Variety V44 is considerably short plant with stability in 12 desirable characters namely yield, fruit number, dry weight, capsaicin level, days to dry, low percentage of bleaching, good colour and acceptable mean fruit weight appear to meet the specification of the dry chilli. V44 might not be popular as fresh chilli because the local chilli consumers prefer the long slender fruits of MC11, V58, V57 and V61, which are readily accepted by the local farmers.

Variety Ch388 (V57) with stability in yield, plant height, bleaching and capsaicin and showed acceptable days to dry, conversion rate fruit together and attractive fruits, has potential for fresh consumption. Similarly, the high yielding Ch393 (V61), with extra ordinary good colour together with high capsaicin, with stability in plant height, conversion rate and days to dry has potential for fresh...
consumption. Since both V57 and V61 have good quality attributes and above break even point for conversion rate but are slow to dry, they are not recommended for dry chilli production but are suitable as raw materials in chilli processing industry.

MC11 with long big fruits and showed good quality attributes and dry easily, is a double purpose chilli. It is suitable for fresh consumption and for processing.

Another potential variety for dry chilli production is Purple Chilli (V16). It has good quality characters with stability of Type I in most of these characters and specific adaptability in yield performance. V16 showed better yield in Cameron Highlands, more suitable for cooler region.

Variety Xian (V25) showed stability Type I for conversion rate, fruit number and days to dry and quality characters namely bleaching, colour, capsaicin. Like V16, this variety appeared vigorous and high yielding in cooler region of Cameron Highlands. Being an exotic variety from China, it is not surprising that this variety showed specific adaptability in yield and best recommended for cultivation at higher elevation.

The high yielding cili padi like Huey Sithon (V39), is an alternative to cili padi both in pungency and fruit size. Huey Sithon is an annual, matures early and shows tendency for synchronised fruiting, a growth habit which is desirable for large-scale production. The other cili padi like variety is Ch252-C-P (V49), a tall variety of average yield. It appeared to yield better in the lowlands rather than in cooler areas of highland. V49 is stable in plant height, fruit number, colour, capsaicin, dry weight, conversion rate and percentage of bleaching. Like V39, V49 also showed good quality attributes with high dry weight and conversion rate and easily dried. It
could be recommended as an interim measure to fulfil the present increasing interest in *cili padi* as raw material in chilli sauce industry.

In dry chilli production, yield is not the only consideration, the existence of environmental influences especially temperature and humidity on ease of drying and percentage of bleaching which are the key factors in dry chilli production should be taken into account. Under Malaysian conditions with high RH of between 71-93 % (Table 4.4). It took about 9 to 18 days for chilli to dry using modified dryer (Plate 1). Such long drying periods would incur higher labour cost and high risk of damage. Under such circumstances, Rasulpuri *et al.* (1972) suggested the adoption of artificial dryer. With artificial dryer the cost of production of per kg of dry chilli is RM 3.90 (Samsudin *et al.* 1992).

To produce one kg of dry chilli, with conversion rates ranging 15-24%, we required about 6.6 - 4.0 kg of fresh chillies. At the production cost of RM 0.72 per kg of fresh chilli (based on yield at the most favourable environment, Cameron Highlands, cost equivalent to produce one kg of dry chilli is RM2.90 - RM4.75. Total cost equivalent to produce a kg of dry chilli under Malaysian condition using artificial dryer is RM 6.80 - RM 8.65. While the cost of imported dry chilli is RM4.00 - RM 8.00. There is no economic advantage to produce dry chilli under the current situation.

Since it is not economical to produce dry chilli locally unless cheaper drying methods are available, it is suggested that local chilli be processed wet to chilli paste. The recent introduction of chilli paste to substitute for dried chilli as component in making chilli sauce.
First planting-season

Second planting-season

Figure 5.1. Yield as influenced by climatic factors: rainfall, temperature, sunshine and relative humidity during growing period
Plate 2. Variety Brebes (V44): A medium size plant, above average yielder with good quality attribute and most stable variety with stability in twelve characters
Plate 3. Variety purple chilli (V16) selected for characters: days to dry (stable), pungency (stable), fruit number (stable), conversion rate, good colour (stable), high colour retention (stable) on drying and yield (stable). Stability in 9 characters.
Plate 4. Variety MC 11 selected for good fruit size (stable), optimum height (stable), high yield (stable), pungency (stable), conversion rate (stable), no of fruits/plant (stable), days to dry (stable). Stability in 11 characters. MC11 is a double purpose chilli. The glossy bright red (solar dried) and very intent red colour (oven dried) of MC11.
Variety Ch388 (V57) selected for characters: yield (stable), pungency (stable), fruit number (stable), conversion rate (stable) and long attractive fruits (stable) suitable for fresh consumption and as raw material. Stability in 11 characters.