# STUDIES ON DIMENSIONAL STABILITY AND VARIATION IN MOISTURE CONTENT OF KILN DRIED WOOD SAMPLES OF TEN INDIGENOUS SPECIES OF BANGLADESH

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## INTRODUCTION

Wood is a hygroscopic substance. It has the ability to adsorb and desorb moisture. When wood is exposed to atmospheric condition its moisture content adjusts itself until it is in equilibrium with the moisture content of the surrounding atmospheric humidity. The equilibrium moisture content of wood is dependant on the atmospheric temperature and relative humidity and consequently a change in temperature and relative humidity will bring about a change in the moisture content of wood. This fluotuation of moisture content is generally accompanied by a corresponding change in the dimension of the wood. The situation becomes complicated by the fact that the dimensional change is not same for all the species. Some timbers are comparatively stable in respect of shrinkage and swelling while others are more susceptible to such changes causing trouble during wood in service, particularly in joinery work, such as, drawers, doors and windows, etc. Thus knowledge on the seasonal variation of moisture content of different species of wood and their concomitant dimensional changes is of considerable practical importance in determining their suitability for good quality furniture and cabinet manufacture. A study was, therefore, undertaken to evaluate the relative dimensional stability properties of some of the indigenous wood species of Bangladesh where temperature and relative humidity conditions of the atmosphere between the winter and monsoon months vary widely.

## OBJECTIVES

The principal objectives of this study were (1) to determine the seasonal variation of moisture content of kiln dried timber of ten indigenous species of Bangladesh, (2) to determine the dimensional change of those wood species as affected by different seasons of the year due to fluctuation of moisture content, and (3) to evaluate the effect of exposure on the dimensional changes that may occur in actual service condition.

## EXPERIMENTAL PROCEDURE

Sample preparation: Two sets of matched samples were prepared from the kiln dried lumber of each of the following wood species:

1. Simul (Salmalia malabarica)
2. Kadam (Anthocephalus cadamba)
3. Gamar (Gmelina arborea)
4. Suruj (Codrela toona)
5. Civit (Swintonia floribunda)
6. Champa (Michelia champaca)
7. Teak (Tectona grandis)
8. Koroi ( Albizzia procera)
9. Chikrassy (Chukrassia tabularis
10. Garjan (Dipterocarpus turbinatus)

The selected samples were free from drying degrades and were 30 inch x 6 inch x 0.75 inch in dimension. They are mixed sawn to conform to the conditions normally prevailing in practical use. The initial moisture content of the samples, prior to exposure, was 12±1.5 percent.

Exposure of samlpes: Two specially designed wooden racks were prepared for hanging each set of samples in such a manner that air could circulate freely around the individual specimen which was allowed to expand and contract without any physical restraint. One set of samples was placed in an open shed with probable exposure to outdoor conditions and another set was placed in the auditorium of the Institute to simulate conditions prevailing in the interior of a house.

## COLLECTION AND ANALYSIS OF DATA

The dimension measurement was taken in the length, width, and thickness directions of each specimen. For length measurement, a small triangular metal brad was firmly fixed in each sample approximately 3.5 inch from both ends. A line was drawn between the brads and measurements were taken along this line with the help of an 18 inch metallic scale and a slide caliper having an accuracy of 1/128 inch. The width of the sample was measured with the slide caliper to the nearest 1/128 inch and the thickness was measured with a micrometer screw gauge to the nearest 1/1000 inch. Priod to dimension measurement, the weight of the individual specimen was taken on a Toledo balance to an accuracy of 1/100 lb.

All the weight and dimension measurement s were made at one month interval for a period of seventeen months. At the end of the exposure period, 1 inch moisture section was cut from the centre of each specimen and the final moisture content of the individual sample was determined. Based on this final moisture content, the estimated oven-dry weight of each sample was calculated. The moisture content values of the individual samples at the end of each month of exposure were then determined from their current and estimated oven-dry weights.

The monthly changes in moisture content of the wood samples representing ten species under two exposure conditions were determined by taking difference between initial moisture content values prior to exposure which were taken as base values and the successive moisture content values during exposure. The percentage moisture content changes, with respect to base values of individual samples, were then calculated. Similarly, the accompanying dimensional changes in the width, thickness and length directions were determined and were expressed as percentage dimensional changes with respect to the base values of individual samples. The decrease and increase in dimension resulting from moisture content fluctuation represent shrinkage and swelling respectively. The shrinkage and swelling in the length direction were negligible and as such were omitted from the analysis. As most of the samples were mixed sawn, the shrinkage and swelling in the width and thickness directions did not represent the shrinkage and swelling in either true tangential or radial direction. To ascertain whether there was any significant difference between the width and the thickness values t-test of difference between the data representing width and thickness values was performed for all the species under both the conditions of exposure. The summary of the results of t-test is contained in Table 1. It will appear from this Table that out of a total of 19 samples (one sample was left out of the analysis due to some anomaly in the data), variation in shrinkage and swelling between width and thickness directions was found to be non-significant in 15 samples while it was found significant in four samples. On physical examination of the latter samples, it was observed that the maximum portion of each of those specimens was flat sawn; thus the dimensional changes in the width direction represented practically the values in the tangential direction. The higher tangential values in the width direction were responsible for the significant difference in the four samples. Further, samples placed in the open shed and samples placed inside the building, were subjected to more or less similar atmospheric conditions. It was quite probable that the effect of exposure under the above two conditions would not be appreciably different. It was confirmed by the t-test of difference between the mean values as obtained in the open shed and in the auditorium (Table 1). Out of nine species, seven showed no significant difference and two were found significant at the 5% level of probability. Since the t-test of difference between mean dimensional changes in the width and thickness directions and two conditions of exposure showed non-significant results in most cases, the monthly shrinkage and swelling values in the width and thickness directions under two conditions of exposure expressed as percentage of the base values were averaged for each species and plotted graphically together with the corresponding moisture content changes.

Table 1: Results of t-test to determine significance between dimensional changes in the width and thickness directions and two conditions of exposure.

| Species | Exposure Condition | t-test of significance: difference between mean width and thickness data — t-value calculated | Significance | difference between mean shed and auditorium data — t-value calculated | Significance |
|---|---|---|---|---|---|
| Simul | Auditorium | 1.44 | N.S. | 1.34 | N.S. |
| | Open shed | 3.38 | ** | | |
| Kadam | Auditorium | 0.26 | N.S. | 1.92 | N.S. |
| | Open shed | 0.61 | N.S. | | |
| Gamar | Auditorium | 1.62 | N.S. | 0.23 | N.S. |
| | Open shed | 4.75 | *** | | |
| Suruj | Auditorium | 1.23 | N.S. | 0.61 | N.S. |
| | Open shed | 1.20 | N.S. | | |
| Civit | Auditorium | 0.66 | N.S. | 0.59 | N.S. |
| | Open shed | 0.66 | N.S. | | |
| Champa | Auditorium | 1.75 | N.S. | 2.16 | * |
| | Open shed | 1.50 | N.S. | | |
| Teak | Auditorium | 0.56 | N.S. | 1.18 | N.S. |
| | Open shed | 0.77 | N.S. | | |
| Koroi | Auditorium[3] | 0.82 | N.S. | – | – |
| | (Open shed) | – | – | | |
| Chikrassy | Auditorium | 0.81 | N.S. | 0.80 | N.S. |
| | Open shed | 0.85 | N.S. | | |
| Garjan | Auditorium | 2.92 | ** | 2.39 | * |
| | Open shed | 2.89 | * | | |

* Significant at 5% level of probability.
** Significant at 1% level of probability
*** Significant at 0.1% level of probability
N.S. Not significant.
(3) Data of open shed was excluded from the study due to some anomaly in the data.

The mean monthly relative humidity, temperature and rainfall based on the climatological data of the Forest Research Institute, Chittagong during the period May, 1964 to August, 1965 are represented in Figure 1. Also included in the graph is the equilibrium moisture content of wood based on the temperature and relative humidity data. Figures 2-11 show the mean monthly shrinkage and swelling and corresponding moisture content changes during the period of exposure for different species. From the shrinkage and swelling curves, the average maximum shrinkage and swelling values of each species along with their respective moisture content changes were determined. These values are shown in Tables 2 and 3.

Table 2: Maximum mean shrinkage and swelling values of different species.
(Average of four observations).

| Species | Sp.Gr. (Gr.Vol.) | Maximum shrinkage % | Maximum swelling % | M/C Change Decrease % | M/C Change Increase % | Base M/C (%) |
|---|---|---|---|---|---|---|
| Simul | 0.32 | 0.31 | 0.58 | 13.38 | 33.31 | 12.11 |
| Kadam | 0.32 | 0.34 | 0.80 | 9.74 | 34.68 | 11.82 |
| Gamar | 0.46 | 0.17 | 0.47 | 8.19 | 25.16 | 11.72 |
| Suruj | 0.49 | 0.37 | 0.61 | 10.02 | 20.00 | 13.52 |
| Civit | 0.55 | 0.27 | 0.61 | 9.10 | 24.15 | 10.94 |
| Champa | 0.55 | 0.47 | 0.53 | 8.48 | 25.58 | 11.61 |
| Teak | 0.60 | 0.14 | 0.37 | 3.74 | 23.70 | 10.63 |
| Koroi | 0.63 | 0.22 | 0.50 | 7.20 | 11.90 | 12.42 |
| Chickrassy | 0.65 | 0.27 | 0.78 | 7.31 | 21.40 | 13.16 |
| Garjan | 0.65 | [illegible] | 0.63 | 4.61 | 19.88 | 11.91 |

Table 3: Comparison of maximum mean swelling and corresponding moisture content change between two successive years.

| Species | Maximum swelling % | | M/C change % | |
|---|---|---|---|---|
| | First year | Second year | First year | Second year |
| Simul | 0.58 | 0.35 | 33.31 | 30.04 |
| Kadam | 0.80 | 0.34 | 34.68 | 32.60 |
| Gamar | 0.47 | 0.27 | 25.16 | 12.83 |
| Suruj | 0.61 | 0.31 | 20.00 | 16.70 |
| Civit | 0.61 | 0.30 | 24.15 | 21.27 |
| Champa | 0.53 | 0.22 | 25.58 | 16.95 |
| Teak | 0.37 | 0.14 | 23.70 | 20.01 |
| Koroi | 0.50 | 0.22 | 14.49 | 12.10 |
| Chickrassy | 0.78 | 0.51 | 21.40 | 20.09 |
| Garjan | 0.63 | 0.35 | 19.88 | 17.56 |

## DISCUSSION OF RESULTS

It appears from Figures 1-11 that there as an apparent correlation between the climatological data of the Institute campus where the wood samples were exposed and the moisture content and dimensional changes of each species under investigation. The highest relative humidity which gave the highest equilibrium moisture content was recorded in July and the lowest equilibrium moisture content resulting from the lowest relative humidity was observed in February (Fig.1). Samples of the species were found to adsorb and desorb moisture to the maximum in the months of August and March respectively and consequently maximum dimensional changes were observed in those months (Fig.2-11). It might be noted here that the effect of climatological conditions on the wood samples was not reflected in the same month, but in the following month, because measurements of wood samples were taken at one month interval in the first week of the following month. Data of all species followed the same general pattern of shrinkage and swelling. It is evident from the results that the rate of dimensional changes was not equally proportional to the moisture content change for all the species. The maximum average shrinkage, for example, recorded in the case of champa was 0.47 percent corresponding to a decrease of 8.48 percent in moisture content while for the same order of moisture content decrease, the maximum average shrinkage was only 0.17 percent in the case of gamar (Table 2). It is further evident that the increase in moisture content and its accompanying swelling was comparatively higher in the first year than that of the second year (Table 3), although the rainfall of first year was appreciably lower than that of the subsequent year. From Figure 1, it is found that the average rainfall of June, July and August for 1964 was 27.25 inch compared to 36.50 inch for 1965. The equilibrium moisture content, which is directly related to dimensional changes, was also lower in the first year of exposure (18.0%) in comparison with that of the following year (18.7%). It is, therefore, probable that the wood samples became relatively stable in respect of dimensional changes after the first year of exposure. No such observation could be made for shrinkage since shrinkage data for two consecutive years were not available.

Table 2 further reveals that there was no apparent correlation between the specific gravities and dimensional changes. It is observed by many workers that the higher the specific gravity, the greater the dimensional changes (Newlin & Wilson, 1919; Markwardt & Wilson, 1935; Stamm & Loughborough, 1942). In the present study, No such trend was observed. This might be attributed to (i) the limited number of specimens employed and also to (ii) the difference in the experimental procedure. The samples in the present study were not exposed to controlled relative humidity and temperature conditions, but they were exposed to oscillating atmospheric conditions and thus dimensional changes could not be related with apecific gravities.

It is a common experience that furniture and cabinet manufactured with teak give satisfactory performance while champa is found to give poor performance in respect of dimensional stability. Such variation in the relative dimensional stability in the two species is also demonstrated in this study. Table 2 shows that teak exhibited least dimensional changes. The average maximum shrinkage and swelling values were o.14 and 0.37 percent respectively which were lowest among the species studied. On the other hand, shrinkage value of champa was found to be the highest and about 70 percent higher than that of teak. The swelling value of champa, although 30 percent higher than that of teak was not found to top the recorded values; kadam exhibited maximum swelling. The fact that shrinkage was maximum in one species and swelling was found maximum in another species might appear, at first hand, to be anomalous. This could be explained if we consider the difference in adsorption and desorption of moisture by the individual species. Champa showed 0.53 percent swelling due to 25.58 percent moisture adsorption while kadam showed 0.80 percent swelling due to adsorption of 34.68 percent moisture. If champa would have adsorbed 34.68 instead of 25.58 percent moisture, it would perhaps have experienced nearly as high a swelling as kadam. Teak is, undoubtedly, the most stable timber since it was least affected by the seasonal variation of atmospheric conditions. Next to teak, in descending order of

FIG. 1 : MEAN MONTHLY TEMPERATURE,RELATIVE HUMIDITY, EQUILIBRIUM MOISTURE CONTENT AND RAINFALL

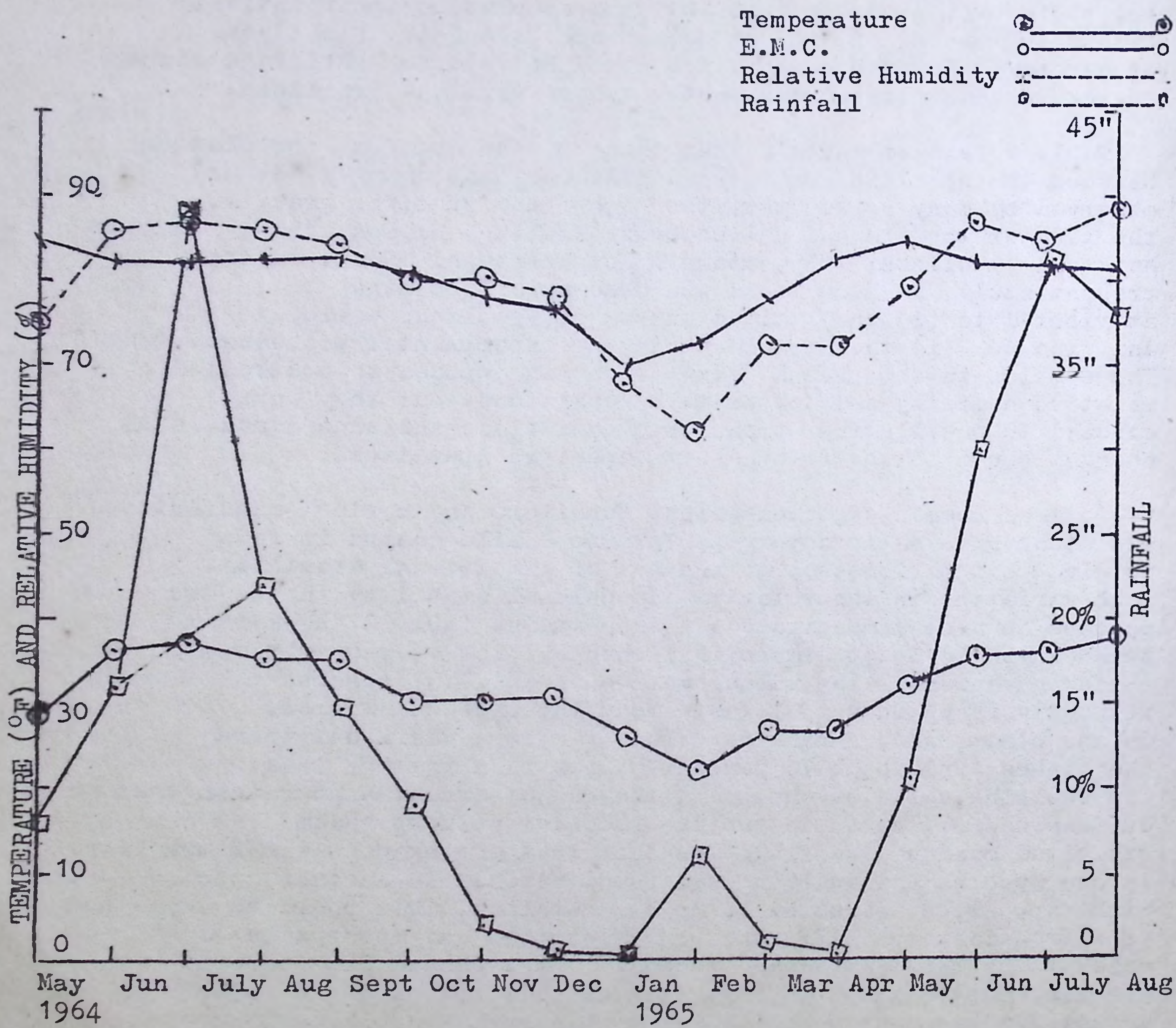
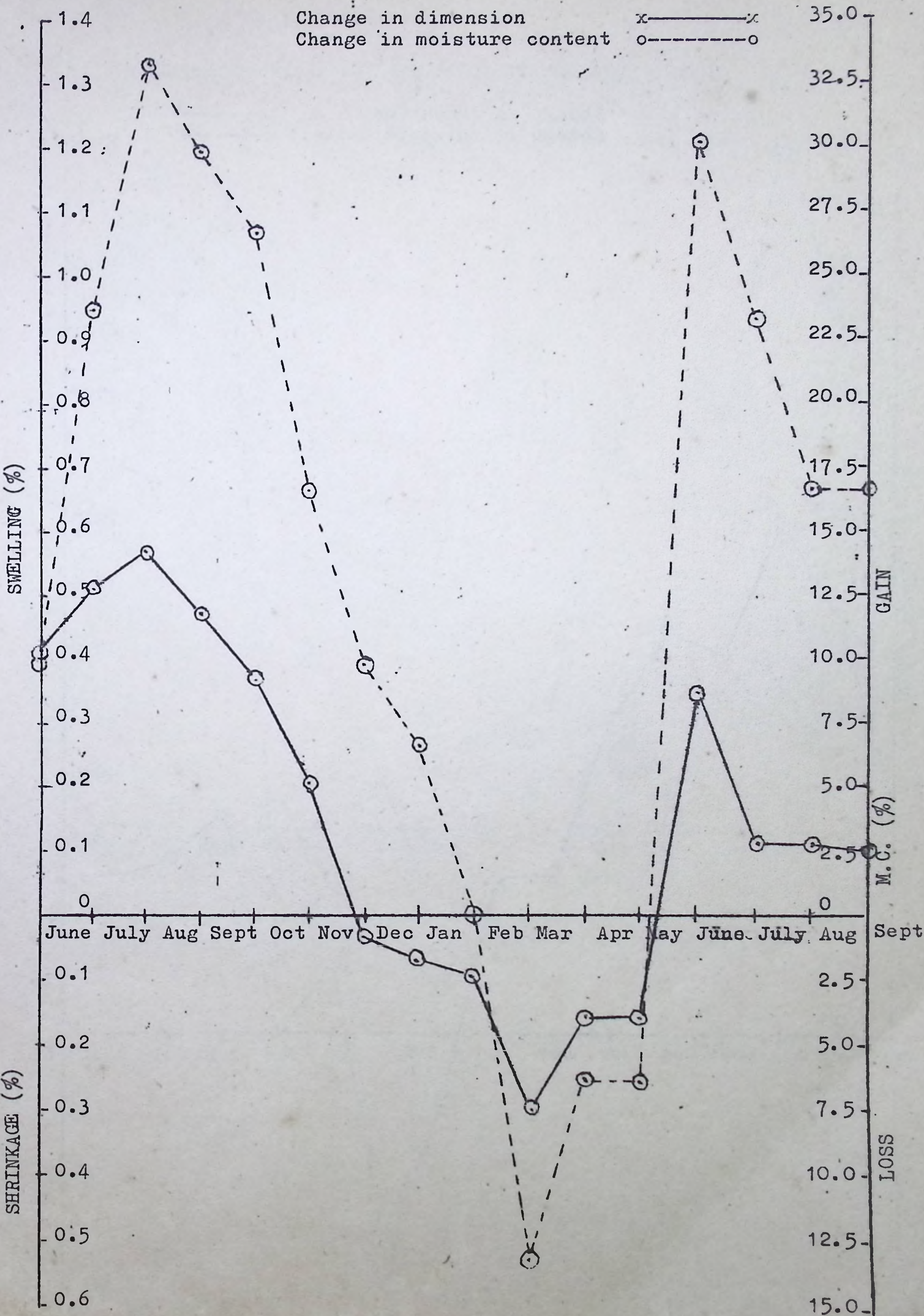


FIG. 12 : DIMENSION AND MOISTURE CHANGE CURVES OF SIMUL



GIG. B : DIMENSION AND MOISTURE CHANGE CURVES OF KADAM

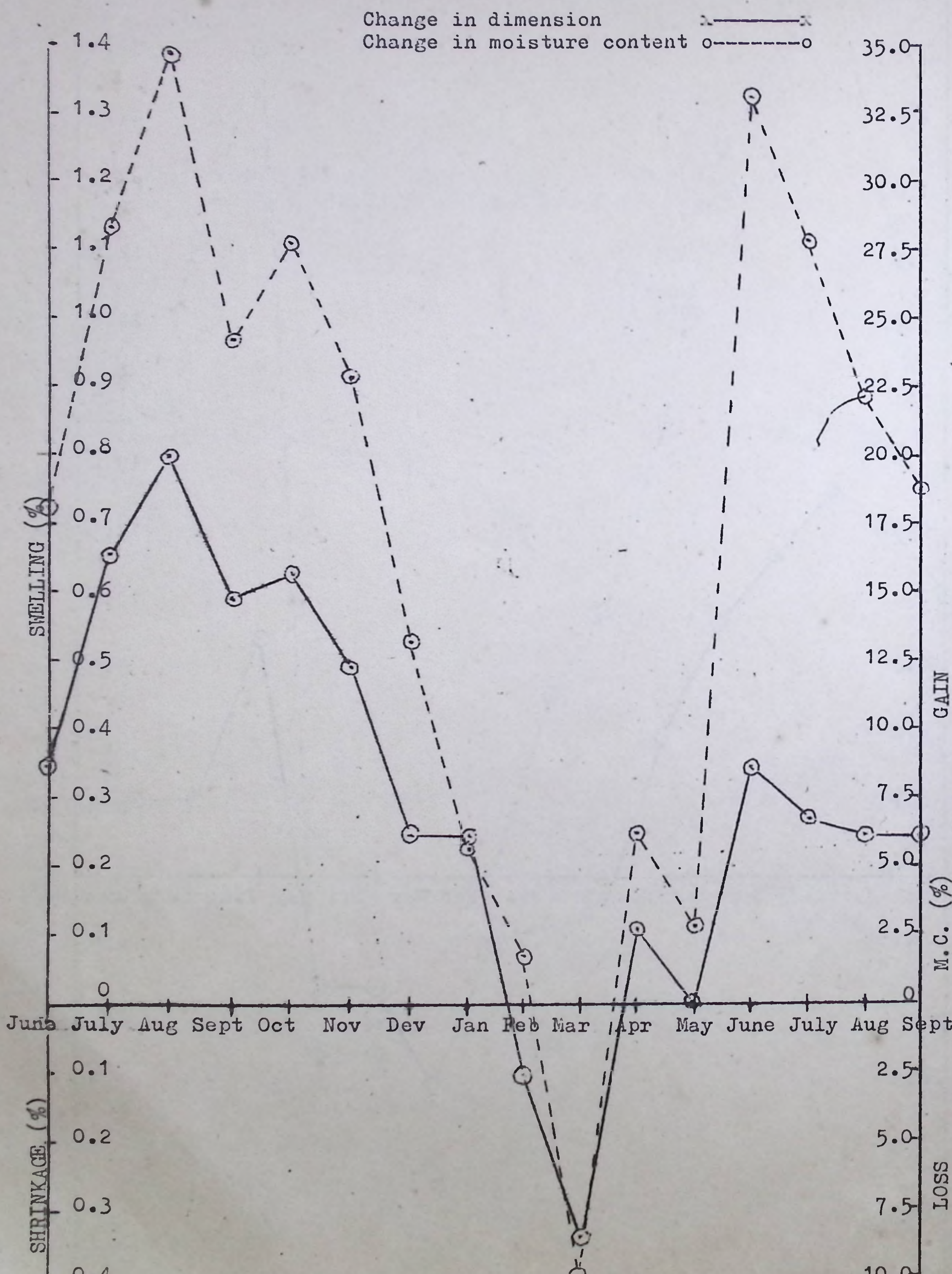


FIG. 4 : DIMENSION AND MOISTURE CHANGE CURVES OF GAMAR

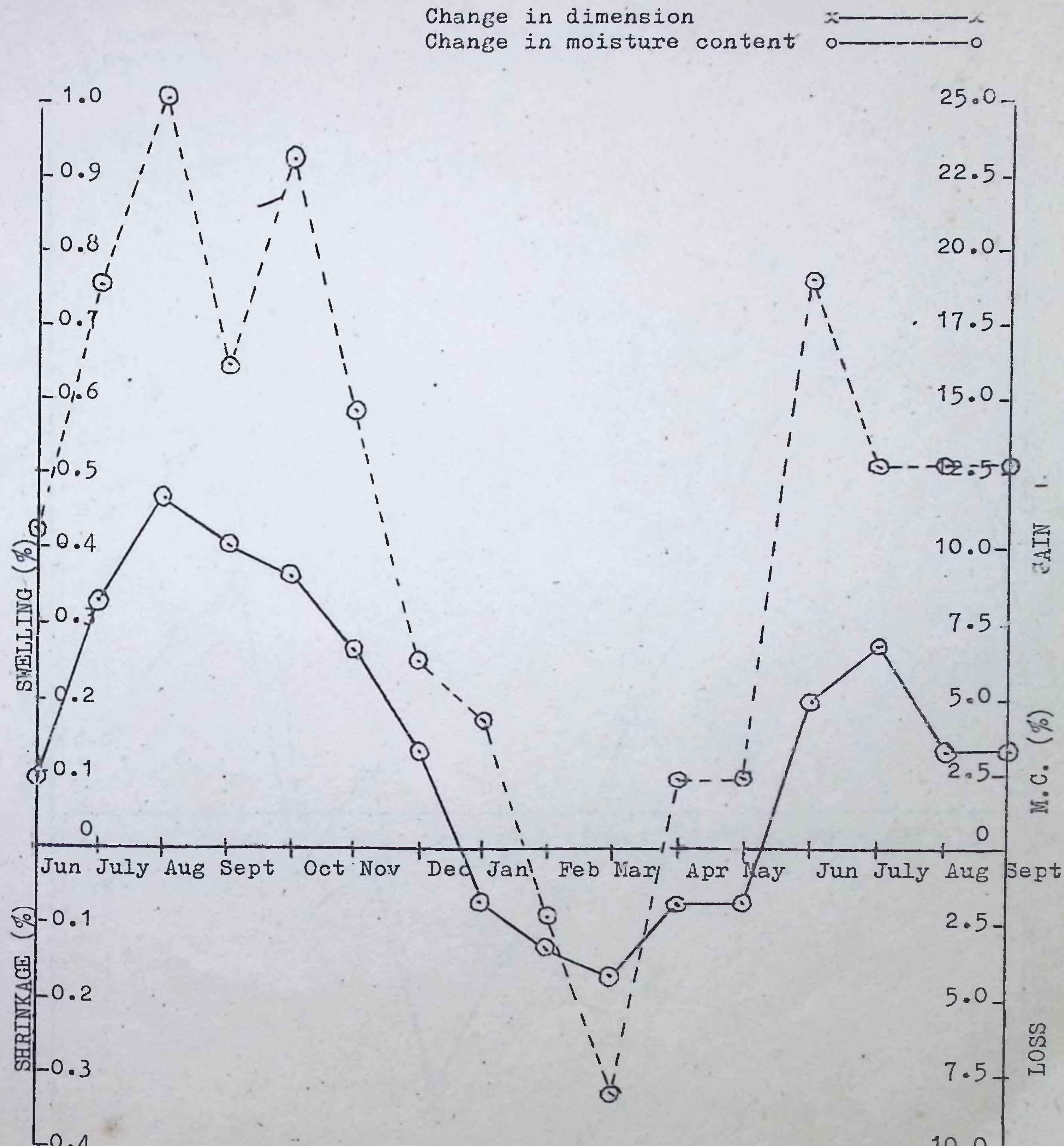


FIG. 5 : DIMENSION AND MOISTURE CHANGE CURVES OF SURUJ

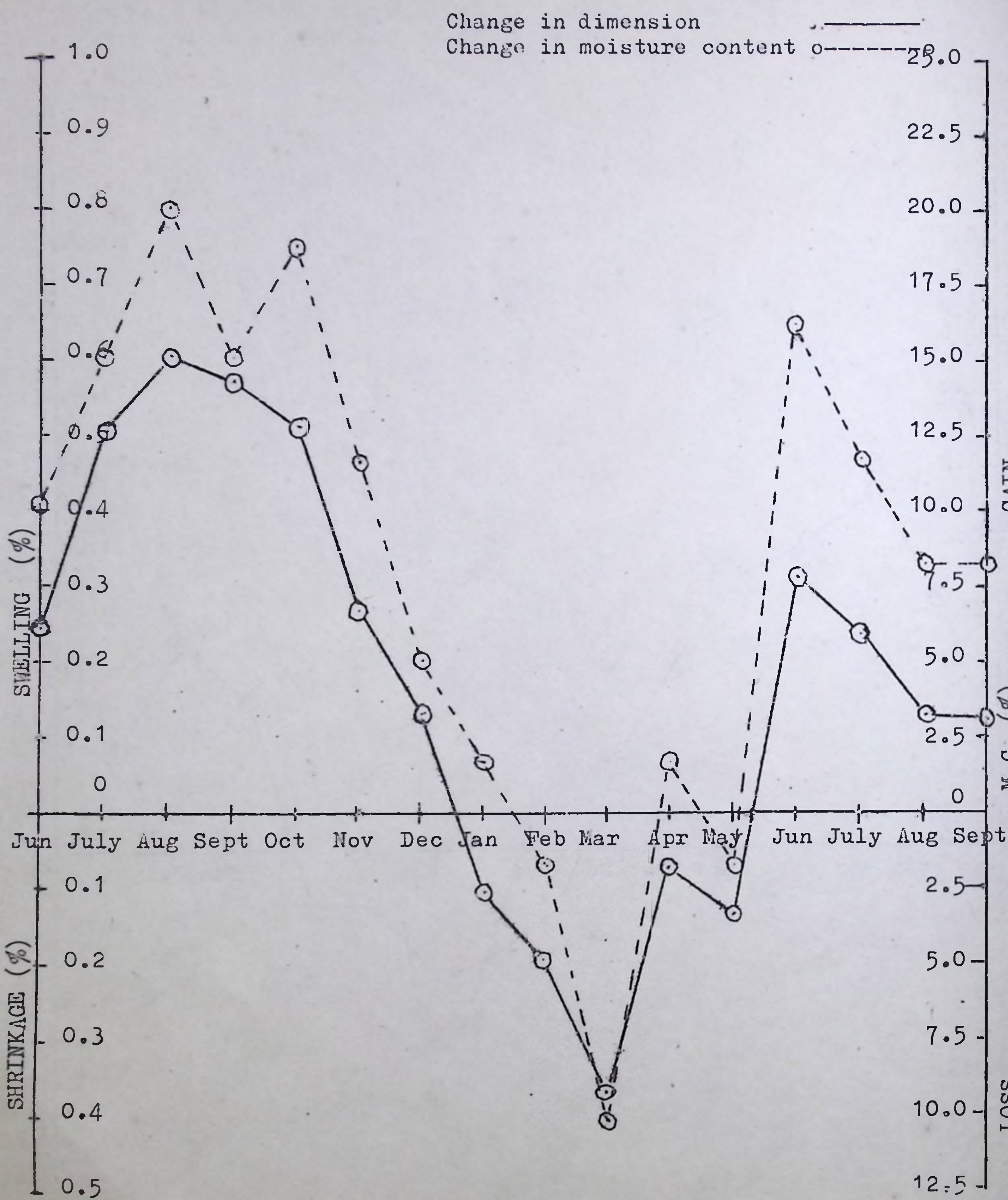


FIG. 6 : DIMENSION AND MOISTURE CHANGE CURVES OF CIVIT

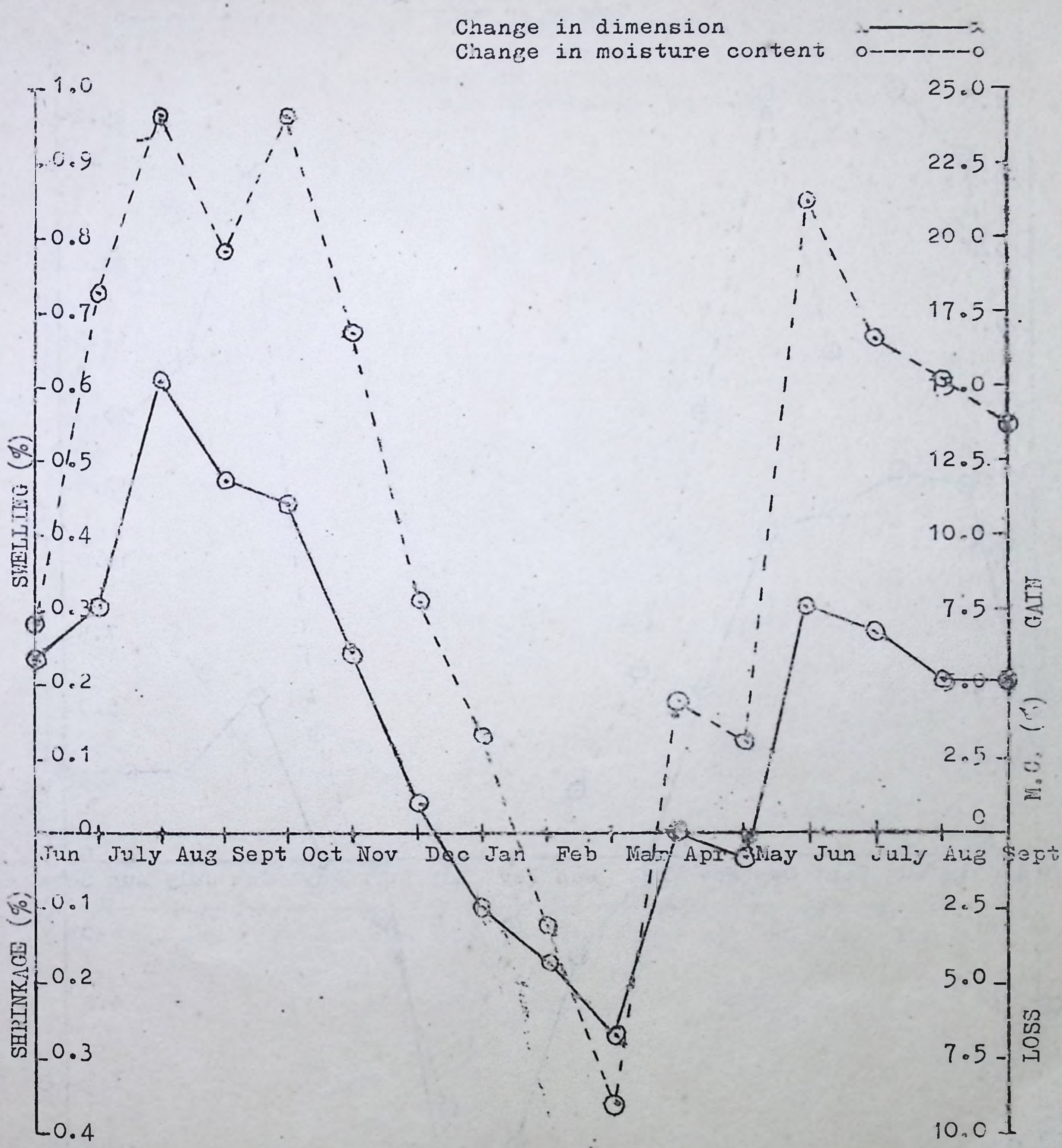


FIG. 7 : DIMENSION AND MOISTURE CHANGE CURVES OF CHAMPA

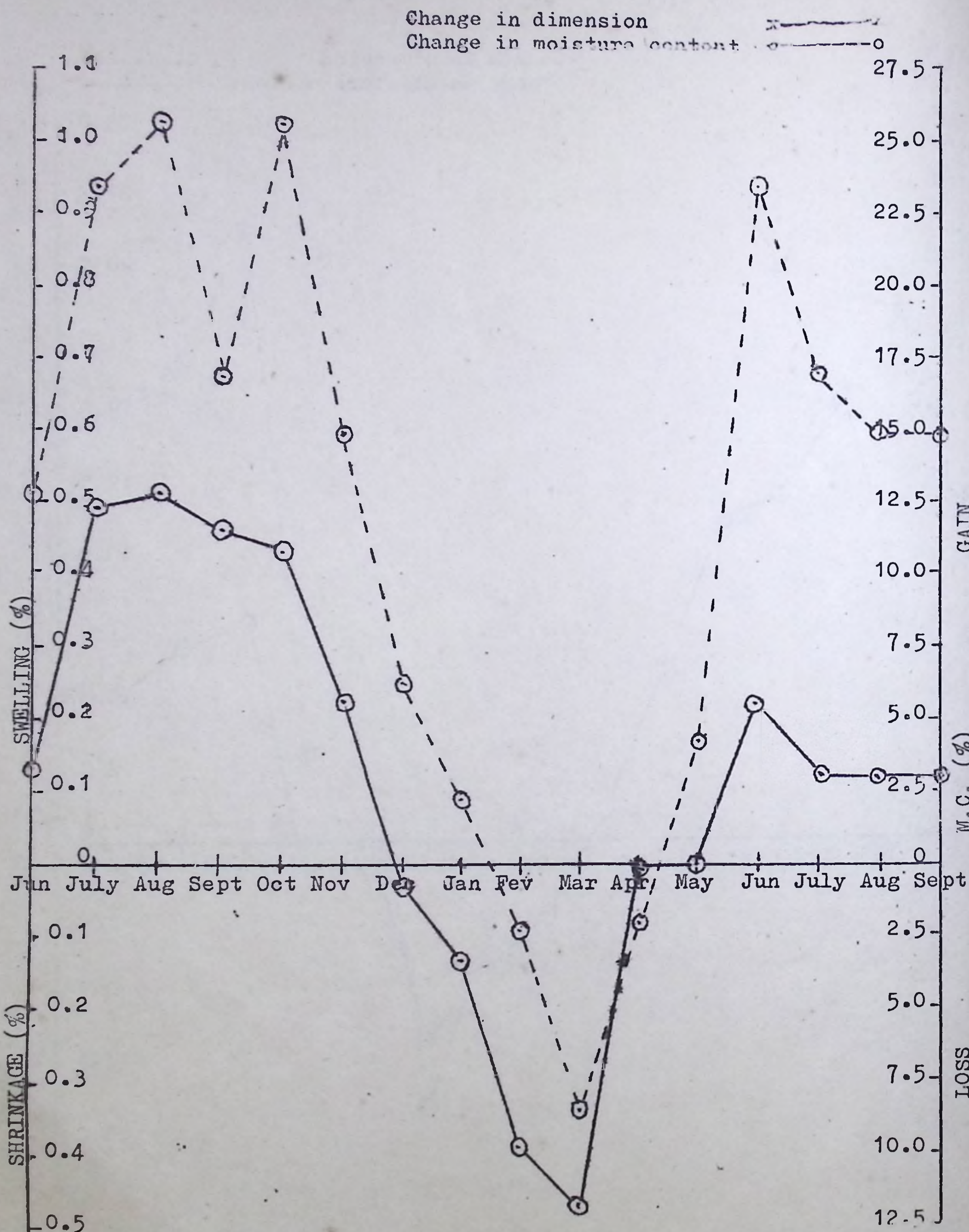


FIG. 8 : DIMENSION AND MOISTURE CHANGE CURVES OF TEAK

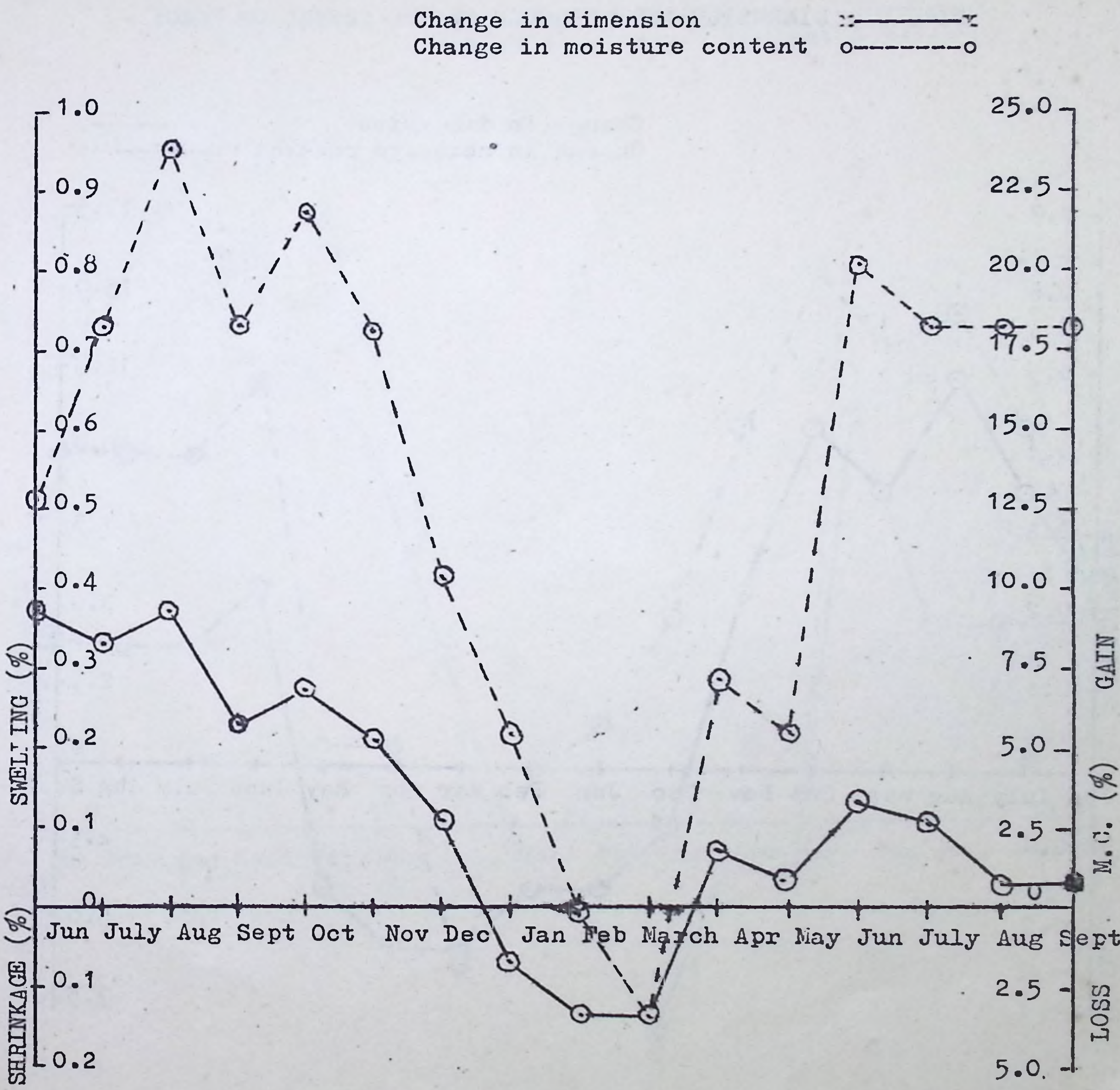


FIG. 9 : DIMENSION AND MOISTURE CHANGE CURVES OF KOROI

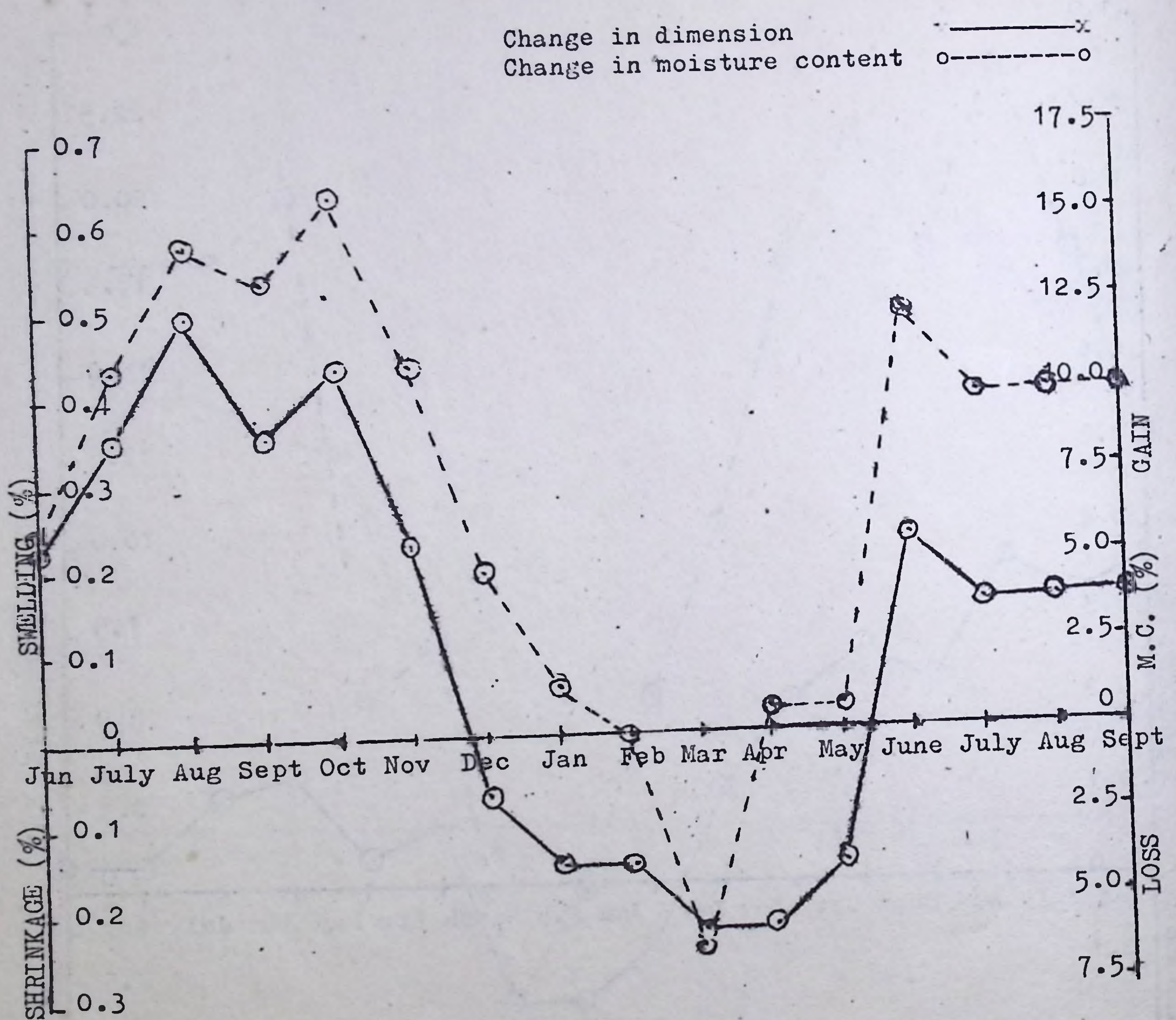


FIG. 10 : DIMENSION AND MOISTURE CHANGE CURVES OF CHICKRASSY

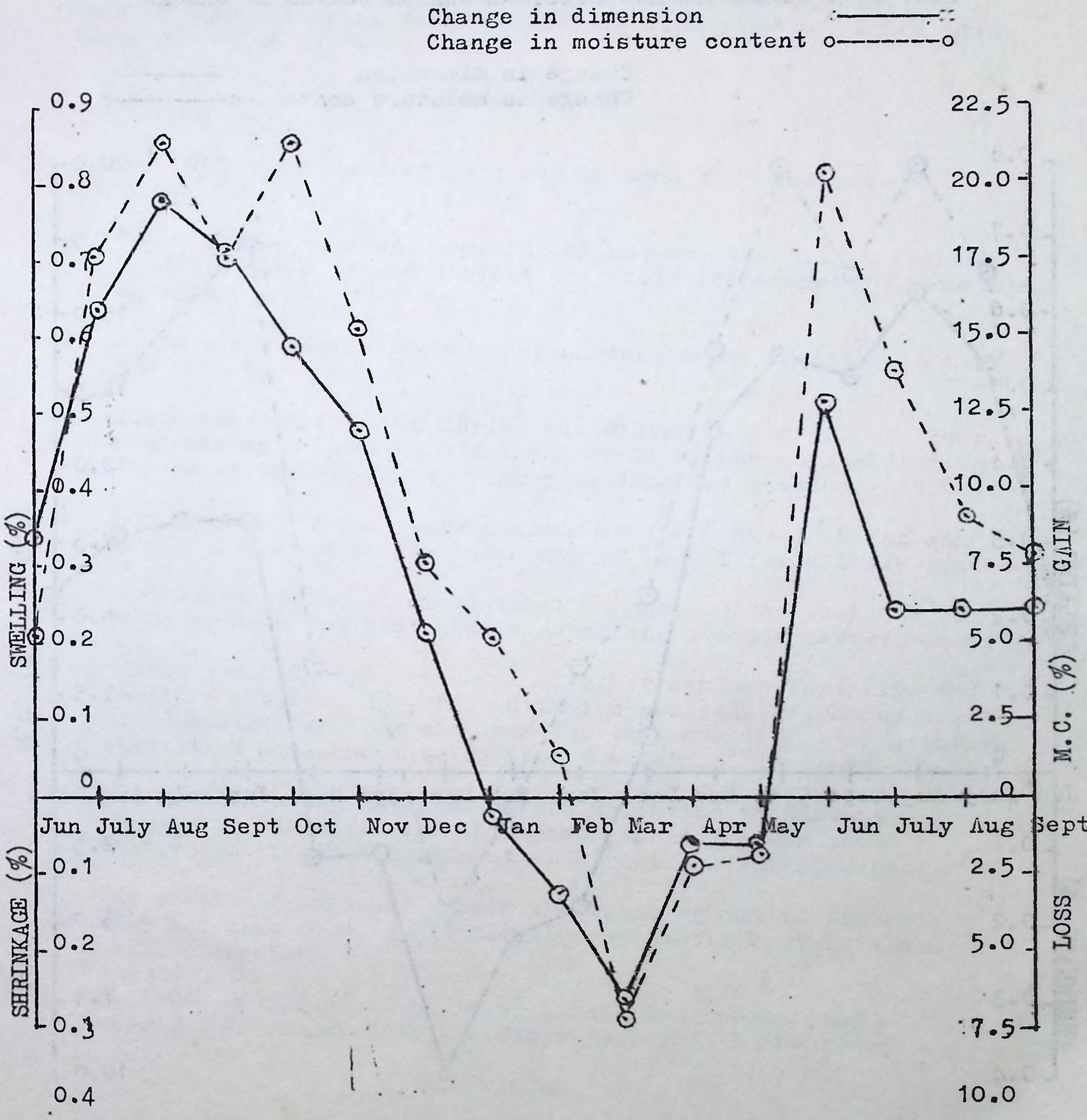
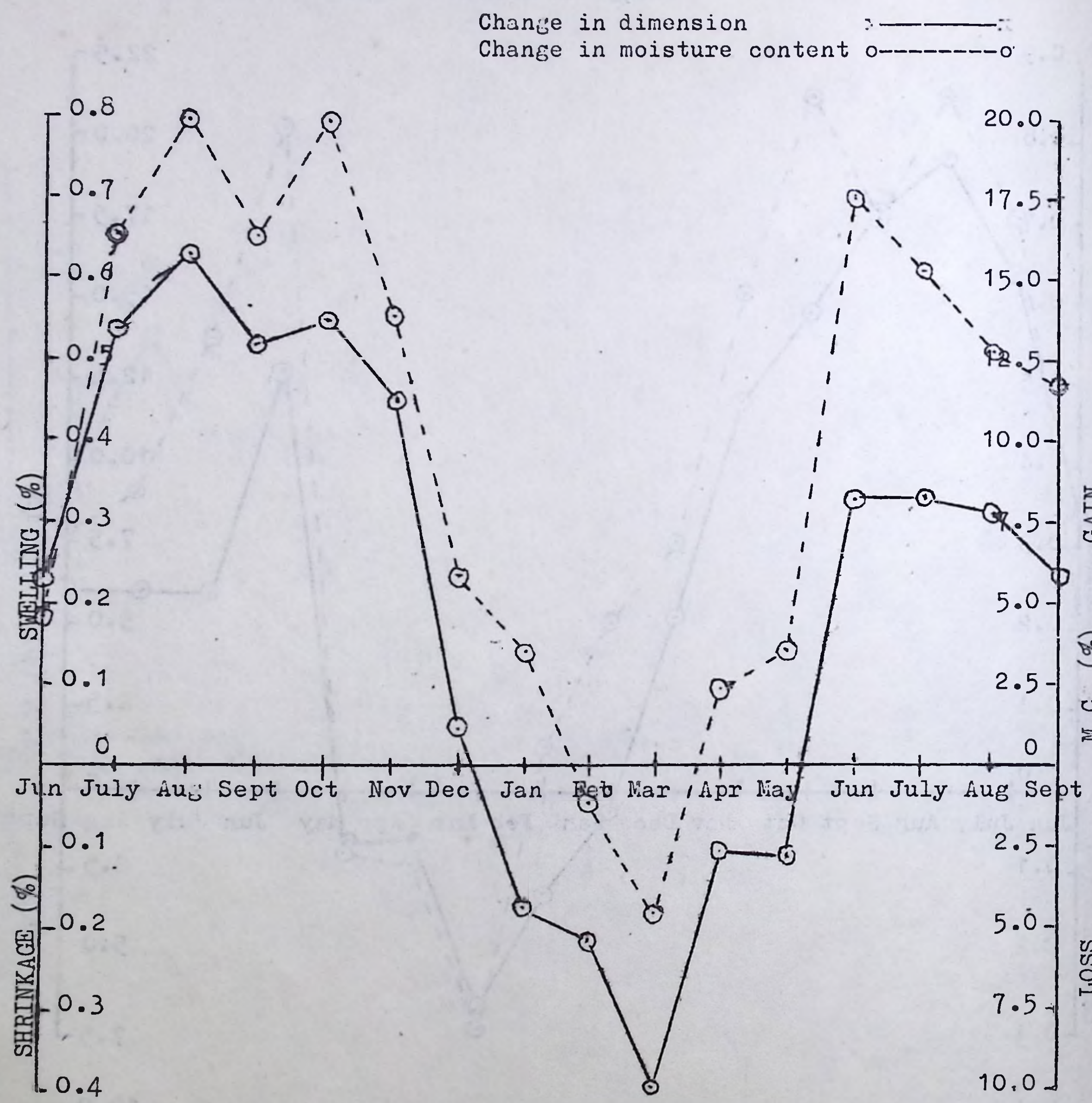


FIG. 11 : DIMENSION AND MOISTURE CHANGE CURVES OF GARJAN



dimensional stability, like gamar and koroi. It may be mentioned that the maximum dimensional changes shown in Table 2 represent average values of mixed sawn sample boards. They are indicative of the relative variation only. In individual cases, e.g., in true flat sawn boards, their values are likely to be higher than those presented in Table 2.

## CONCLUSIONS

The following conclusions could be made from the present investigation:

1. There was an apparent correlation between the climatological data and the moisture content and their accompanying dimensional changes.

2. There was a regular pattern of shrinkage and swelling in all the wood species.

3. Shrinkage was observed during the winter period due to lower equilibrium moisture content and swelling was noticed during the rainy seasons due to higher equilibrium moisture content.

4. Shrinkage was found to be maximum in the month of March and swelling was maximum in the month of August for all the species.

5. Teak exhibited least dimensional changes and as such may be considered as the most stable among the species investigated.

6. Champa and kadam were found to exhibit maximum shrinkage and swelling respectively. The estimated swelling of champa and the observed swelling of kadam for the same degree of moisture adsorbtion were found to be approximately of the same order.

7. The samples being mixed sawn, the variation in dimensional changes in the width and thickness directions was found statistically non-significant in almost all the species.

8. The effect of exposure inside the building and in the open shed was also found statistically non-significant in almost all the species.

9. Swelling was found to be lower during the second year of exposure as compared to the first year in all the species.

## REFERENCES

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2. Newlin, J.A. & Wilson, T.R.C. — 1919 — "The relation of the shrinkage and strength properties of wood to its specific gravity". U.S.D.A., Tech. Bull. No. 676.

3. Stamm, A.J. & Loughborough, W.K. — 1942 — Trans. Am. Soc. Mech. Eng., 63:329.


## SUMMARY


Seasonal variation of moisture content of kiln dried wood samples representing ten indigenous species and their concomitant dimensional changes were investigated under two conditions of exposure. The effect of exposure inside the building and in the open shed was found to be statistically non-significant in almost all the species. The wood samples being mixed sawn, the variation in dimensional changes in thickness and width direction was also found to be statistically non-significant. The climatological mean monthly shrinkage and swelling data for each species were represented graphically. An apparent correlation between atmospheric conditions and dimensional changes was observed. Shrinkage and swelling were found to be maximum in the months of March and August respectively for all the species. Teak exhibited least dimensional changes while champa maximum shrinkage and kadam maximum swelling.


## সারাংশ


ঋতুর প্রভাবে দশ জাতের কেলীন শুষ্ক কাঠের জলীয় অংশ পরিবর্তন সহ উক্ত কাঠের আয়তনের পরিবর্তন দুই অবস্থায় অনুসন্ধান করা হয়েছে। খোলা ছাউনিতে ও ঘরে রক্ষণ জনিত প্রভাব প্রায় সব জাতের কাঠের উপর পরিসংখ্যান মতে অর্থসূচক পাওয়া যায় নাই। চেরাই জনিত কারণে এই কাঠগুলো মিশ্র চরিত্রের হওয়ায় উহার আয়তনের প্রস্থ ও বেধের দিকের পরিবর্তন ও পরিসংখ্যানমতে অর্থসূচক নয়। মাসিক গড় উষ্ণতা, আপেক্ষিক আর্দ্রতা, বৃষ্টিপাত ও কাঠের আয়তনের গড় হ্রাস বৃদ্ধি একে দেখানো হয়েছে। বায়ুমণ্ডলীয় আবহাওয়ার পরিবর্তন ও এই দশ জাতের কাঠের আয়তনের পরিবর্তনের মধ্যে একটি আপাত সম্পর্ক পরিলক্ষিত হয়েছে। সব জাতের কাঠের আয়তনের হ্রাস ও বৃদ্ধি যথাক্রমে মার্চ ও আগস্ট মাসে সব চেয়ে বেশী দেখা গিয়েছে। লক্ষণীয় যে, সেগুনের বেলায় আয়তনের পরিবর্তন সর্বাপেক্ষা কম, কিন্তু আয়তনের হ্রাস ও বৃদ্ধি যথাক্রমে চাম্পা ও কদমের বেলায় সর্বাপেক্ষা বেশী হয়েছে।