CHAPTER 2

Objective 1: Determination of optimal soaking and germination time for wheat and bengal gram grains as indicated by their germinative capacity

Introduction

According to Lorenz (1980), germination of a seed and development of a sprout may be regarded as a number of consequtive steps that increase the metabolic activity of a seed leading to the formation of a protrusion from the seed embryo. The author opined that an adequate water supply, a desirable temperature, a certain composition of gases in the atmosphere and light are the favourable conditions for a viable seed to germinate and develop sprouts.

The first process which occurs during germination of a seed is the uptake of water due to the process of imbibition. The water uptake is not related to the viability of the seeds, because it occurs equally in live and dead seeds. It is influenced by certain factors such as composition of the seed, seed size and the permeability of the seed coat to water (Brookes et al 1976, Mayer and Poljakoff-Mayber 1982). It is generally accepted that the rate of water absorption and the total amount of water absorbed is greater when the initial water content of a grain is low (Baker and Dick 1905). But at the same time, it is believed that the old dry grains absorb water more slowly than the fresh moist ones.

As early as in 1931, Ehrich and Kneip had observed that the nitrogen content of a grain influenced water uptake. The authors had separated a sample of barley (Hordeum vulgare) seeds containing 1.89% nitrogen into 3 fractions. The nitrogen content of the fractions was 1.68 or 1.89 or 2.11%. It was found that the sample with the lowest nitrogen content absorbed water most rapidly. However, this phenomenon did not hold true in case of wheat as wheat grains containing 14.5 or 8.6% protein, gained equal amount of weight on soaking (Frazer and Haley 1932). Likewise in soya bean (Glycine max) no correlation was observed between water absorption and protein content (Hsu et al 1983).

However, Butcher and Stenvert (1973) were of the opinion that the protein content was related to the rate of penetration of moisture. The authors had explored the rate of water uptake by different varieties of wheat and had observed that the variety of wheat which had the highest protein content with considerable deposition of protein in the sub-aleurone regions exhibited the slowest rate of water movement. Since protein has an ability to bind water, the presence of protein in both the bran layers and in the sub-aleurone regions was associated with retardation of movement of moisture into the grain. But a variety of wheat with a similar protein content to that of the other varieties had shown a higher rate of water penetration. Therefore, the authors speculated that some factor other than the protein content could have affected the water movement into the grain. The variety of wheat which had shown highest rate of water penetration was found to have a very open and porous bran structure which was considered to have allowed an easy rapid movement of water. Furthermore, it was speculated that the radial fissures found commonly in this variety of wheat might have allowed a rapid movement of water through the grain. Other factors that were considered to have attributed to the rate of water penetration were the presence of substances in the bran such as hemicelluloses, which are capable of strongly binding water, and the presence of lipid in layers such as testa and aleurone which are believed to act as a physical barrier to the movement of water.

When water imbibition by wheat and corn (Zea mays) was compared, Levari (1960) noticed that wheat had imbibed more water than corn at various soaking periods from one to 48 h and this was attributed to higher protein content of wheat in comparison to that of corn. Although in seeds, the chief component which imbibes water is the protein, other components such as mucilages of various kinds, cellulose and pectic substances also were found to swell. Starch in seeds, on the other hand, do not swell to any appreciable extent even if present in fairly high amounts as in the case of cereal grains (Mayer and Poljakoff-Mayber 1982).

The uptake of water is also influenced by the size of cereal grains (Frazer and Haley 1932). The authors had observed that the smaller sized kernels absorbed moisture most rapidly. Later, Kopecky and Almendinger (1935) demonstrated that large corns initially, absorbed water more rapidly than small ones although after 24 h of soaking the percentage increase in water uptake was similar in large and small sized corns. However, after prolonged steeping (88 h) smaller corns had a greater percentage of moisture than the larger ones. Recently Briggs et al (1981) reported that thin grains took up moisture more rapidly, and reached a higher final water content than did the wider 'bold' grains. Likewise, Hsu et al (1983) had found a negative correlation between absorption rate and kernel size in soya beans, which was attributed to the fact that smaller kernel size provided a larger surface area per unit mass for water transfer. In addition, a linear correlation between the rate of water absorption and bean density has been observed (Hsu et al 1983). Since higher density is generally associated with smaller kernel size and small sized kernels absorbed more water, a linear correlation found between density of a grain and water uptake was understandable.

In 1960, Becker had explained the mechanism of water uptake by the wheat kernels. He stated that the initial water uptake was rapid due to the porous structure of pericarp, the outer most layer of the wheat kernel and this water uptake was due to capillary imbibition. The next layer, testa, was found to be impervious because it lacked an appropriate capillary structure. The only part of the kernel which was not sheathed with testa was the germ end. The rate of water uptake was normally high in this region but because the germ area was small, the effect of this on the total rate of water uptake was not appreciable. It was also noticed that from the testa layer the water diffused into the substance of the kernel by the draining action of diffusion. Hence, the authors concluded that the rate of water absorption was controlled by the rate at which water could diffuse into the substance of the kernel and therefore opined that water uptake was diffusion controlled rather than capillary controlled.

Stenvert and Kingswood (1976) followed the movement of temper water into the bran, germ and endosperm of wheat after one, 3, 6 and 12 h of soaking by the technique of autoradiography. It was observed that initially the water was heavily concentrated in the germ and bran layers. Subsequent movement of water occurred mainly in the dorsal region of the grain and only later in the central crease regions although diffusion from the bran was occurring in all regions.

Hinton (1955) measured the rate of water absorption in wheat kernels from which testa, hyaline layer, and aleurone layer were successively removed, and reported that the testa was the layer offering greatest resistance to water entry. The author had noticed that a fully mealy endosperm was twice as permeable as a fully vitreous endosperm. A mealy appearance was attributed to the presence of many fine air spaces associated largely with the starch grains within the cells. The author opined that presence of such a capillary network was supposed to have assisted the movement of water. Later, Stenvert and Kingswood (1977) also pointed out that endosperm structure was of primary importance in water penetration. A typically soft porous structure allowed a rapid penetration of water into the starchy endosperm. It was also observed that the presence of a more ordered structure strongly retarded the rate of water penetration. At one protein level (9.0%), this difference in structure was reflected by the hardness of the grain. The more closely the protein matrix occluded the starch granules, the resultant harder endosperm exhibited slower rate of water penetration.

That the water absorption varied with the length of time the grains were immersed in water and the temperature of immersion water was reported by Frazer and Haley (1932). The water absorption increased in all varieties of wheat with increase in soaking period from half min to 60 min and also when the temperature of the immersion water was increased from 55 to 100°F. Similarly, Hsu et al (1983) noticed that temperature drastically affected the water uptake by soya beans. At 20°C, the beans took about 10.5 h to reach 90% of the total absorption, at 30°C this same level of absorption took approximately 6 h and at 50°C it took only 2.5 h. At the lowest temperature (20°C) a rapid initial water uptake was observed which was considered to be due to the filling of capillaries on the surface of seed coats and at the hilum. This phenomenon became less obvious at higher temperatures due largely to the increased diffusion rates at higher temperatures.

Brookes et al (1976) illustrated that the water uptake by the seeds generally occurred in 3 phases. Phase one, covering first 6 to 10 h of soaking period, exhibited a rapid water uptake of about 60% of the total. This rapid water uptake was attributed to water imbibition by the seed colloids, primary proteins and carbohydrates. In phase 2, the following 10 to 20 h period, the uptake of water was found to be very slow or at times to have ceased completely. During this period starch was hydrolysed to sugars. It was believed that such hydrolytic processes probably produced increasing osmotic pressure which resulted in the uptake of more water by embryo because by this time, the embryo was found to be sufficiently moist and metabolically active. During phase 3 (over 20 h), again there was a rapid water uptake which was followed by a pleateau. Steeping beyond this phase led to a breakdown of the semipermeable membrane of the grain.

Dewez (1964) working with cotton seed (Gossypium arboreum) explained that the initial rapid water uptake was due to a simple physical wetting of the seed tissues. The following slow water uptake was the result of the metabolic changes induced by growth process. The authors also speculated that between these 2 steps a lag might occur during which water would be absorbed very slowly. Although due to rapid germination of cotton seed no lag between the purely physical and the metabolic water uptake was observed.

The steeping behaviour of 3 varieties of wheat immersed in water for 48 h was explored by Sethi and Bains (1978). In the first 6 h of soaking, the moisture content increased from 5 (0 h value) to 30% and then increased gradually to 42% in 48 h. However, slight variations were observed in water uptake by 3 varieties of wheat as two varieties required an average of 48 h to attain 42% moisture as compared to 36 h required by the third variety. Similarly, Malleshi and Desikachar (1979) had observed slight varietal differences in the water uptake by ragi (Eleusine coracana) grains. The moisture content ranged from 34.5 to 39.9% in 9 varieties of ragi after 24 h of steeping.

Khan et al (1977) had determined the moisture content of maize and sorghum (Sorghum vulgare) grains after steeping for different periods of time. A batch of 100 grains each of the two types were steeped in water. At intervals of 8 h, the wet grains were surface dried by dry filter paper and weighed. In both the grains the absorption was found to be highest in the initial 8 h of steeping (32 to 35%). The maximum moisture gain of 52% was observed at 40 h in maize and of 42% at 16 h in sorghum.

Pathirana et al (1983) had observed that the values for moisture content of sorghum steeped for 18 h was somewhat comparable with those reported by Khan et al (1977). The moisture content of sorghum was 38.2% after 8 h of steeping, 43.7% after 18 h of steeping and 49.8% after 32 h of steeping.

Essery et al (1954) had steeped barley grains in water for one, 4 and 6 h, and observed that the water uptake in terms of weight gain of one h steeped barley was 19.8% which increased to 30.8% after 4 h of steeping and to 34.8% after 6 h of steeping. Later, Kirsop et al (1967) had reported that the total moisture content of barley after 24 h of steeping was 39.0% which increased to 41.1% after 36 h of steeping and to 44.8% after 48 h of steeping.

More recently, Gupta et al (1985) determined the steeping characteristics of 2 varieties of triticale (Triticale hexaploid). The authors observed that the absorption of water in both the varieties of triticale during the first 12 h of steeping was markedly faster than that at the latter steeping hours (up to 48 h).

Malleshi and Desikachar (1982) had soaked ragi and green gram (Phaseolus radiatus) in distilled water for different periods up to 40 h and determined their moisture contents at various intervals. In ragi, the moisture content increased from the initial value of 13 to 28 and 34% after 10 and 20 h of soaking, respectively, after which it remained constant. Likewise, in green gram the moisture content increased from the initial value of 10 to 55 and 60% after 10 and 20 h of soaking, respectively, and thereafter showed no marked increase up to 40 h of soaking. As in the case of triticale (Gupta et al 1985), in ragi and green gram grains the moisture content increased up to 20 h and thereafter showed no marked increase until 40 h. Inamdar (1980) had conducted a study to explore the water uptake by wheat and bengal gram grains by determining the increase in weight of the grains steeped for 6, 12, 24 and 48 h. She found that there was a progressive increase in weight of both the grains after steeping.

The effect of volume of soaking water on water absorption or moisture content has also been explored. Silva and Braga (1982) soaked whole dry beans (Phaseolus vulgaris) for 3, 6, 12 and 24 h in bean weight to water volume ratio of 1:3 or 1:10. It was observed that volume of water made no appreciable difference in water absorption and moisture contents of the grains. After 3, 6, 12 and 24 h of soaking in 1:3 bean to water ratio samples, the absorbed water was 48, 78, 98 and 100 g/100 g, respectively while in 1:10 bean to water ratio samples it was 51, 81, 95 and 105 g/100 g, respectively. The moisture contents of 1:3 bean to water ratio samples ranged from 45 to 56% while that of 1:10 bean to water ratio samples were between 50 and 57% during 24 h of soaking.

Germination capacity of cereals and pulses has also been determined. Sethi and Bains (1978) had estimated the germination capacity of 3 varieties of Indian wheats. One hundred kernels of each variety in quadruplicate were placed in petridishes on thick filter paper. Water was sprayed lightly at intervals to ensure germination. The tests were carried out in a germinator at 20°C. The percent germination of one variety of wheat was 92; of the second, 82; and of the third, 80.

Essery et al (1954) maintained records of germinative capacity of barley grains soaked and germinated for various periods of time. It was observed that none of the grains soaked for one or 2 h had germinated even after the entire germination period of 72 h. But when, the steeping time was 3 h, 20% of the grains were found to be germinated after 24 h of germination and this figure increased to 27 and 33% after 48 and 72 h of germination period. When the steeping time was increased to 4 h, the percentage of germination was 57% after 24 h of germination and 58% after 48 and 72 h of germination. When the steeping time was further increased to 5 h, the percentage of germination remained 97% at 12, 24 and 72 h of germination. Further increase in steeping time brought about no variations in percentage of germination in response to germination periods. It was 98% at all the germination periods. These data indicated that 5 to 6 h of steeping was sufficient to achieve 97 to 98% germination, at 24, 48 and 72 h of germination periods.

Malleshi and Desikachar (1982) had soaked ragi and green gram in distilled water for different periods up to 40 h and germinated them for 24 and 48 h, respectively. Samples were withdrawn at suitable intervals and percentage of germinated grains was determined. It was observed that 75% of grains had germinated after 10 h of soaking. When the soaking period increased to 20 h, the percentage of germination increased to 90%. Thereafter with further increase in soaking time the percentage of germinated grains tended to decline. In case of green gram, the percentage of germinated grains was 92% after 10 h of soaking and then remained almost constant until 40 h of soaking.

In 9 varieties of ragi, soaked for 24 h and germinated for 3 days, Malleshi and Desikachar (1979) had found that percent germination ranged from 67 to 98%. Chavan et al (1981) had observed that 97 to 98% of low and high tannin cultivars of sorghum were germinated by 120 h. These data indicated that in ragi varietal differences influenced percent germination while in sorghum tannin content made no impact on percent germination.

At a given soaking period the germination capacity was found to vary in response to germination period. Aisien and Ghosh (1978) had observed that the percent germination of sorghum grains increased with increase in germination time. It was 16% after 12 h of germination and the value had doubled (34%) by the end of 18 h of germination. It was 43% after 24 h of germination and 87% after 36 h of germination. It became 93% after 48 h of germination and 95% after 54 h of germination. Percentage of germination was 97% after 60 h of germination and it did not change when the germination time was extended by another 6 h.

As early as in 1942, '44, Kneen et al and Kneen had demonstrated that sprout development is influenced by germination temperature. Kneen et al (1942) had observed that wheat grains took one day at 20°C, 2 days at 15°C, 3 days at 10°C and 6 days at 5°C to develop sprout ~~of~~ length of one to 2 mm. In another study, Kneen (1944) observed that after 2 days of germination, wheat grains had sprout length of one millimetre at 14°C, 2.5 mm at 18°C, 4 mm at 24°C and 7.5 mm at 30°C. These data indicated that sprout development is slow at low temperatures.

Hamad and Fields (1979) had germinated wheat, barley, oats (<u>Avena byzantina</u>) and rice (<u>Oryza sativa</u>) and had found that on the sixth day the coleoptiles of the grains ranged from 2.5 to 3.5 inches in length.

Inamdar (1980) had reported that after 12 h of soaking and

12 h of germination the sprout length of wheat grains was 0.6 cm which increased to 1.1 and 1.9 cm when the germination period was increased to 24 and 48 h, respectively. Likewise, the sprout length of bengal gram which was 1.7 cm after 12 h of germination increased to 2.1 and 3.2 cm after 24 and 48 h of germination, respectively. The results indicated that sprout length of wheat and bengal gram increased with the increase in germination time.

Ram et al (1979) germinated 2 varieties of maize seeds and observed no appearance of the primary root after one day of germination in both the varieties. In one variety, the primary root length was 1.4 cm after 2 days of germination which increased to 4.6 cm after 3 days of germination, and to 8.3 cm after 4 days of germination. Further increase in germination period led to decay of tips. In the second variety, the sprout length linearly increased with increase in germination period to 5 days. It was 3.3 cm after 2 days of germination, 4.8 cm after 3 days of germination, 5.4 cm after 4 days of germination and 6.5 cm after 5 days of germination. These data indicated that variety of a grain influenced sprout development during seedling growth.

Aisien and Ghosh (1978) had also observed that coleoptile length of sorghum grains increased with increase in germination time. After 12 h of germination, sprouts were just observed and the coleoptile length became 0.5 mm after 18 h of germination. It doubled (1.0 mm) after 24 h of germination and increased 6 times (6.0 mm) after 48 h of germination. The coleoptile length of 66 h germinated sorghum seeds was 2.0 to 2.5 cm.

Chavan et al (1981) had germinated low and high tannin cultivars of sorghum for 120 h. The root and shoot lengths were measured at 48 h intervals. After 48 h of germination the root and shoot lengths of low tannin variety of sorghum were 3.4 and 4.5 cm, respectively. A progressive increase in root and shoot lengths was observed up to the germination period of 120 h when the root length was 14.4 cm and the shoot length, 20.8 cm. Likewise, in high tannin variety of sorghum, the root and shoot lengths were 1.4 and 0.9 cm, respectively, after 48 h of germination which increased progressively to 8.8 and 13.8 cm after 120 h of germination. The root and shoot lengths were markedly suppressed in high tannin seedlings as compared to low tannin seedlings. These observations indicated that tannins might be responsible for retarding seedling growth during early stages of germination.

The sprout length has been observed to vary with germination time and seed type. Khan and Ghafoor (1978) had reported that the sprout length of mash beans germinated for 48 h was between one to 2 cm. Abdullah and Baldwin (1984) had reported that sprout lengths of 8 h soaked and 3 days germinated mung bean (*Phaseolus aureus*) was 5.2 cm and of soya bean was 4.2 cm.

In nutshell, germination brings about an increase in the metabolic activity of a grain leading to the formation of a sprout. A number of environmental factors, such as, water supply and temperature affect the rate of germination and modification of a grain. The factors that affect water uptake are initial moisture content, grain size, nitrogen content, and structure and composition of grain layers (Lorenz 1980). But the available information is scanty regarding the germinative capacity of wheat and bengal gram in response to soaking for various periods. Therefore, this experiment was planned to determine an optimal soaking time for wheat and bengal gram grains in terms of their germinative capacity at 24 or 48 h of germination period.

The parameters in relation to soaking periods were (a) moisture content of the grains, (b) percentage of germinated grains after 24 and 48 h of germination and (c) percentage of grains having measurable sprout lengths of more than 0.2 cm and non-measurable sprout lengths of less than 0.2 cm. The percent germination and sprout length of grains were the indicators of germinative capacity.

The percentage of germinated grains would indicate the extent of soaking required to achieve maximum germination and the percentage of germinated grains with measurable and non-measurable sprout lengths would reflect upon the length of germination time necessary to have maximal germinated grains with an appreciable sprout length. The sprout length would give an indication of the growth of the seedling.

Materials and methods

Cleaned grains were soaked in thrice their volume of water at room temperature of 29°C (25 to 34°C) for 24 h. For the determination of the moisture content at various soaking periods of 4 to 24 h at 2 hourly intervals, in triplicate, approximately

2 g of wheat and 4 g of bengal gram grains, surface dried by filter paper, were kept in an oven at 65°C for 24 h and then weighed. Rf

At each 2 h time intervals of soaking, in triplicate, 100 grains were germinated for either 24 or 48 h. For germination, the soaked grains were wrapped in a single layer of moist muslin cloth and kept in petridishes. After 12 h of germination, the muslin cloth was wetted again. The petridishes were covered with a wire mesh. A moist muslin cloth covered the wire mesh to prevent moisture evaporation.

After 24 and 48 h of germination, germinated grains from each petridish were counted to calculate percent germination. The sprout lengths of randomly picked up 10 grains from each petridish were measured. The germinated grains having measurable and non-measurable sprout lengths were separated and counted.

The standard errors of the means were calculated (Snedecor and Cochran 1968).

Results and discussion

For maximal germinative capacity of wheat and bengal gram grains germinated for 24 or 48 h, the optimal soaking time was determined in terms of moisture content, percentage of germinated grains and percentage of germinated grains with measurable sprout length at soaking periods of 4 to 24 h.

Moisture content and germinative capacity of grains at different soaking periods

Wheat: Table 1 displays the mean values for moisture content and germinative capacity of wheat grains soaked for various periods and germinated for 24 h. The moisture content of wheat grains increased 4 fold over its initial value of 6.0% after 4 h of soaking period (Table 1). Thereafter, it continued to increase up to 24 h of soaking period but the rate of increase in moisture content was relatively slow in grains soaked for more than 12 h. The mean value for moisture content of wheat grains was 35.1% after 12 h of soaking. The trend in the increase in moisture content, that is, initially rapid followed by a slow increase compared well with that reported by Brookes et al (1976). Earlier, Dewez (1964) had opined that the initial rapid water uptake was a purely physical process while the slower water uptake was caused by the metabolic changes in the soaked grain. Khan et al (1977) had also observed that the rate of water absorption was more in the initial periods of steeping in both maize and sorghum seeds.

Similar results were reported by Sethi and Bains (1978). The authors had observed that after 6, 12, 18 and 24 h of steeping, the wheat grains had attained 29, 34, 37 and 38% moisture, respectively. These values reported by Sethi and Bains (1978) were in close accordance to those observed in the present study at each soaking period of 6 (29 Vs 30%), 12 (34 Vs 35%), 18 (37 Vs 38%) and 24 h (38 Vs 41%).

Table 1. Moisture content and germinative capacity of wheat grains soaked for various periods and germinated for 24 h.

Soaking period (h)	Moisture content (%) (Mean ± SE)	Percent germina -tion (%)	Percentage of germina -ted grains with sprout length less than 0.2 cm (%)	Sprout length of randomly selected 10 grains with sprout length more than 0.2 cm ~~(cm)~~ (Mean ± SE)
0	6.0 ± 0.020			
4	26.6 ± 0.459	70.3	78.7	0.38 ± 0.042
6	30.3 ± 0.243	93.0	48.1	0.43 ± 0.028
8	31.7 ± 0.147	95.7	41.8	0.45 ± 0.040
10	33.8 ± 0.478	98.7	20.0	0.54 ± 0.020
12	35.1 ± 0.018	100.0	12.3	0.60 ± 0.035
14	36.0 ± 0.289	99.3	5.3	0.62 ± 0.067
16	36.9 ± 0.096	98.7	6.8	0.78 ± 0.052
18	38.4 ± 0.107	99.3	3.3	0.80 ± 0.035
20	38.6 ± 0.124	99.3	4.3	0.80 ± 0.018
22	39.7 ± 0.411	98.7	6.8	0.83 ± 0.009
24	40.7 ± 0.070	94.7	7.4	0.85 ± 0.026

Levari (1960) had monitored water uptake by wheat grains at different soaking periods in terms of increase in original grain weight. The author had reported that the water uptake by wheat grains at 6, 10 and 24 h of soaking were 33, 40 and 51%, respectively. Inamdar (1980) had reported somewhat higher values than those reported by Levari (1960). The water uptake by wheat grains after 6 h of soaking was 37%; after 12 h, it was 59%; and after 24 h of soaking, it was 74%.

The initially rapid followed by slow increase in moisture content has also been observed in grains other than wheat. Malleshi and Desikachar (1982) had reported that the moisture content of unsoaked ragi was about 13% which increased to nearly 27% following 10 h of soaking and about 37% following 20 h of soaking. Thereafter, the enhancement of soaking period to 40 h caused a minimal increase in the moisture content of ragi grains.

Table 1 shows that about 70% of the wheat grains were germinated as a consequence of 4 h of soaking and 24 h of germination. With the increase in soaking period from 4 to 24 h, the percentage of germinated grains ranged from 93 to 100%. Cent percent germination was observed in 12 h soaked wheat grains but thereafter, no consistant trend was observed until 20 h of soaking period. In wheat grains soaked for over 20 h, that is from 22 to 24 h, the germinative capacity tended to decline from 98.7% in 22 h soaked to 94.7% in 24 h soaked grains.

In wheat grains soaked for 4 h and germinated for 24 h, 78.7% of the grains had germinated but had non-measurable sprout length (Table 1). With the increase in soaking period the percentage of germinated grains with non-measurable sprout length tended to decrease. It became 41.8% after 8 h of soaking and decreased to 20.0 and 12.3% after 10 and 12 h of soaking, respectively. These data indicated that about 88% of the 12 h soaked and 24 h germinated wheat grains had measurable sprout lengths (more than 0.2 cm). In wheat grains soaked for more than 12 h no consistant trend was observed in percent germinated grains having non-measurable sprout length although the values tended to be lower as compared to that observed in 12 h soaked grains (Table 1).

In response to 24 h of germination the mean value for sprout length of 4 h soaked wheat was 0.38 cm, it increased by 0.22 cm (0.38 to 0.60 cm) when the seeds were soaked for 12 h (Table 1). With prolongation of soaking period to 24 h, the sprout length consistently increased but the rate of increase was markedly slow after 16 h of soaking. Inamdar (1980) had reported that the sprout length of 12 h soaked and 24 h germinated wheat grains was 1.1 cm which was higher than that recorded in the present study (0.62 cm). The difference in results could be due to varietal differences in grains used in the two studies as has been suggested by Ram et al (1979).

When 4 to 24 h soaked wheat were germinated for 48 h, the germinative capacity ranged from 95 to 100% (Table 2). It was observed that even 4 h of soaking was enough to produce about 99% of germination. However, with the increase in soaking period

Table 2. Germinative capacity of wheat grains soaked for various periods and germinated for 48 h.

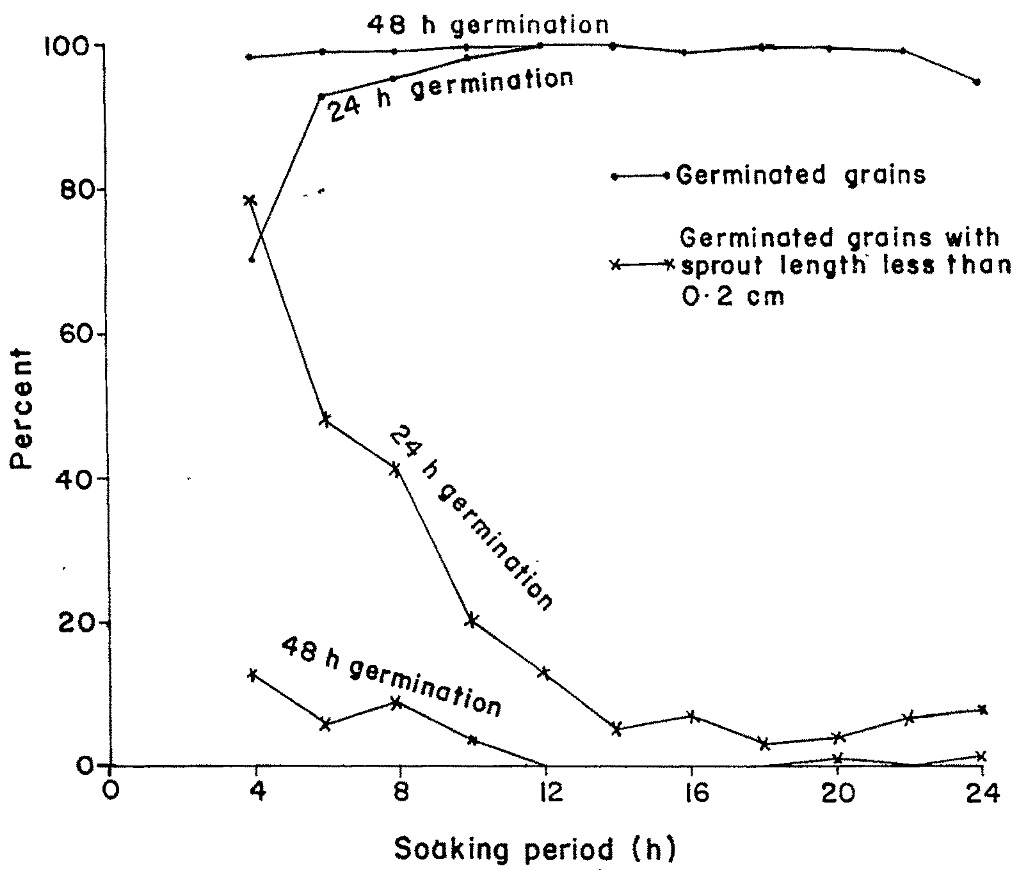
Soaking period (h)	Percent germination (%)	Percentage of germinated grains with non-measurable sprout length less than 0.2 cm (%)	Sprout length of randomly selected 10 grains with measurable sprout length more than 0.2 cm ~~(cm)~~ (Mean ± SE)
4	98.7	13.2	1.62 ± 0.124
6	99.3	6.0	1.72 ± 0.121
8	99.3	9.1	1.89 ± 0.152
10	99.7	3.7	2.07 ± 0.121
12	100.0	0.0	2.32 ± 0.087
14	100.0	0.0	2.53 ± 0.249
16	99.3	0.3	2.63 ± 0.058
18	99.7	0.0	2.66 ± 0.022
20	99.3	1.0	2.75 ± 0.067
22	99.0	0.3	2.83 ± 0.111
24	95.0	1.4	2.88 ± 0.232

to 12 and 14 h the percent germination became 100%. Thereafter, no consistent trend was observed in percentage of germinated wheat grains soaked for 14 to 24 h. As a matter of fact the germinative capacity showed a decline in grains soaked for 24 h. It was 99.0% in grains soaked for 22 h and it decreased to 95.0% in grains soaked for 24 h (Table 2). A similar decrease in germinative capacity of wheat grains was observed when the soaking period was increased from 22 to 24 h and the grains were germinated for 24 h. Comparing the germinative capacity of grains soaked for various time periods and germinated for 24 h or 48 h, it was observed that at each soaking period until 12 h of soaking, the percentage of germinated grains was higher after 48 h than after 24 h of germination (Fig. 1). Irrespective of the germination period, the 12 h soaked grains exhibited cent percent germination.

In response to 48 h of germination, the percentage of germinated grains with non-measurable sprout length decreased from 13.2 to 3.7% when the soaking period was increased from 4 to 10 h (Table 2). Thereafter, until 24 h of soaking, almost all the grains germinated for 48 h had measurable sprout lengths.

Comparing the percentage of germinated grains with non-measurable sprout length, it was observed that at each soaking period until 12 h of soaking the percentage of germinated grains with non-measurable sprout length was lower in 48 h than in 24 h germinated wheat grains. Thereafter no consistent trend emerged but the values of 48 h germinated grains remained lower than

Fig I. Germinative capacity of wheat grains after 24 and 48 h of germination periods



those of the 24 h germinated grains. However, the maximum decrease in germinated grains with non-measurable sprout length was observed after 12 h of soaking regardless of germination period (Fig 1).

Holding the soaking period constant and varying the germination time, it was observed that after 4 h of soaking, the percentage of germinated grains with non-measurable sprout length was 78.7% after 24 h of germination but the same was 13.2% after 48 h of germination (Tables 1, 2). Similarly, after 12 h of soaking period the percentage of germinated grains with non-measurable sprout length was 12.3% after 24 h of germination in comparison to zero percent in grains germinated for 48 h. These data suggested that regardless of soaking period, increase in germination period decreased the percentage of grains with non-measurable sprout length.

In wheat grains germinated for 48 h, the mean value for sprout length increased with increase in soaking time. The mean value for sprout length of 4 h soaked wheat grains was 1.62 cm which increased progressively to 2.88 cm until 24 h of soaking period (Table 2). An increase of 0.70 cm in the mean value for sprout length was observed within the first 12 h of soaking (from 1.62 to 2.32 cm) and an additional increase of 0.56 cm (from 2.32 cm to 2.88 cm) was observed with the increase in soaking period from 12 h to 24 h. Comparing the sprout length of grains germinated for 24 and 48 h, it appeared that at each soaking period, the sprout length of grains germinated for 48 h was higher than that of grains germinated for 24 h. Such relationship of sprout length with germination period has been reported earlier (Aisien and Ghosh 1978, Ram et al 1979, Inamdar 1980, Chavan et al 1981).

In nutshell, it appeared that wheat grains soaked for 12 h and germinated for 24 or 48 h exhibited 100% germinative capacity. Moreover after 48 h of germination each of these grains had sprout length more than 0.2 cm. Therefore, 12 h of soaking period and 48 h of germination period were considered optimum for the germination of wheat grains.

Bengal gram : Table 3 presents the data on the moisture content and germinative capacity of bengal gram grains soaked for various periods and germinated for 24 h. It was observed that the mean value for moisture content of bengal gram increased about 8 fold (from 5.7 to 44.2%) after the first 4 h of soaking period. Thereafter, the increase was gradual until 12 h of soaking (from 44.2 to 53.9%). No further increase in moisture content was recorded with the increase in soaking period from 12 to 24 h. Inamdar (1980) had reported that the water uptake by bengal gram grains steeped for 6, 12 and 24 h was 75, 76 and 93%, respectively. The rate of water uptake between 12 and 24 h of soaking period was much higher than between the soaking periods of 6 and 12 h. This observation was not in line with that made by Dewez (1964) and Brookes et al (1976).

In the present study, the initial increase in moisture content of bengal gram was higher than that observed by Malleshi

Table 3. Moisture content and germinative capacity of bengal gram grains soaked for various periods and germinated for 24 h.

Soaking period (h)	Moisture content (%) (Mean ± SE)	Percent germination (%)	Percentage of germinated grains with non-measurable sprout length less than 0.2 cm (%)	Sprout length of randomly selected 10 grains with sprout length more than 0.2 cm ~~(cm)~~ (Mean ± SE)
0	5.7 ± 0.072			
4	44.2 ± 0.546	54.0	29.6	0.46 ± 0.044
6	51.0 ± 0.571	60.0	33.3	0.50 ± 0.078
8	52.8 ± 0.212	77.0	34.2	0.55 ± 0.025
10	52.5 ± 0.529	87.3	30.4	0.58 ± 0.028
12	53.9 ± 0.133	83.3	32.4	0.59 ± 0.058
14	53.7 ± 0.124	86.3	32.4	0.61 ± 0.006
16	54.5 ± 0.170	87.3	28.3	0.61 ± 0.025
18	54.3 ± 0.552	91.0	22.0	0.65 ± 0.059
20	53.2 ± 0.350	91.7	18.9	0.68 ± 0.030
22	54.3 ± 0.290	92.3	17.6	0.73 ± 0.061
24	54.3 ± 0.409	91.3	20.5	0.74 ± 0.024

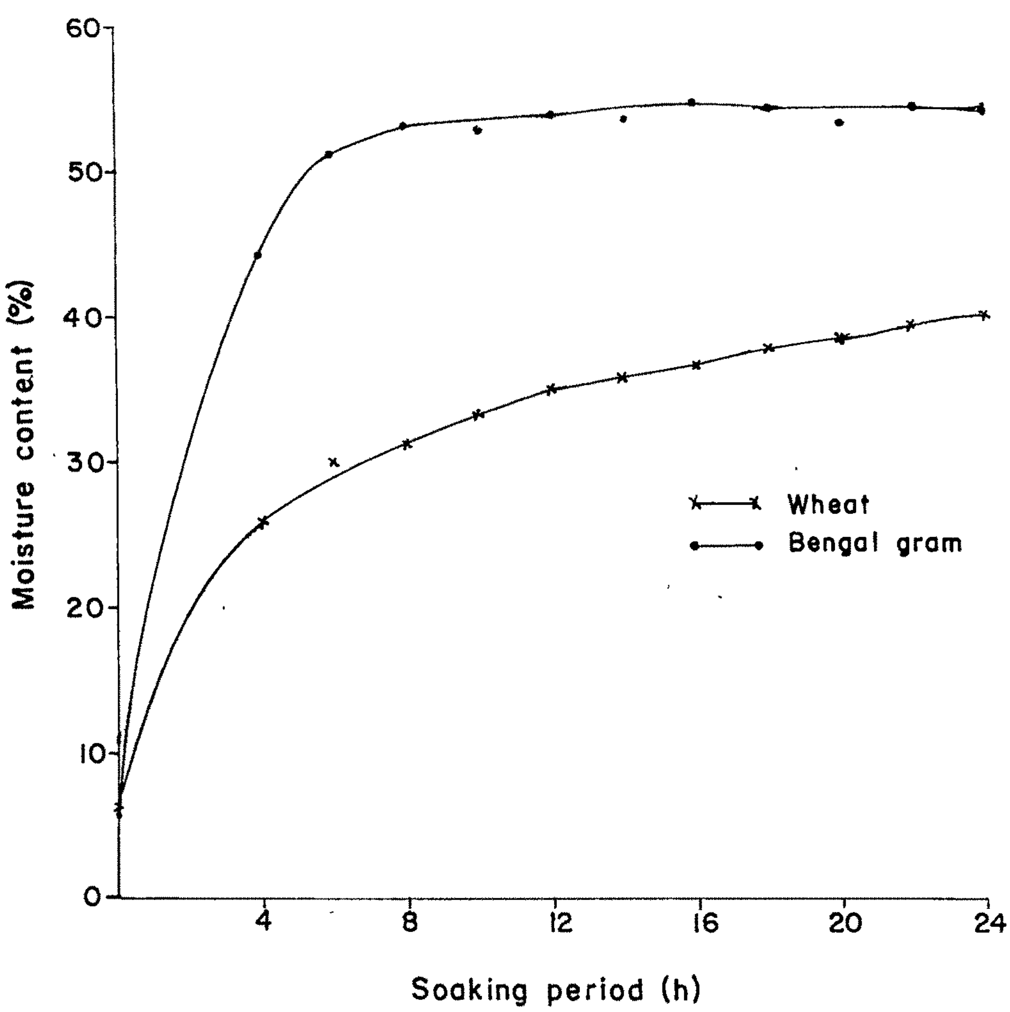
and Desikachar (1982) in green gram. The difference in moisture contents of bengal gram and green gram at various soaking periods might be due to their different physical and compositional characteristics such as size, nitrogen content and initial moisture content of the grain which might have affected the water uptake by the grains (Brookes et al 1976, Mayer and Poljakoff-Mayber 1982).

Figure 2 shows that in both wheat and bengal gram grains the increase in moisture content was very rapid until 4 h of soaking. Thereafter it was relatively slow until 24 h of soaking. But at each soaking period the moisture content of bengal gram was nearly 20% higher than that of wheat grains.

Table 3 also reveals that in response to 4 h of soaking and 24 h of germination, 54.0% of the grains were found to have germinated. With the increase in soaking period from 6 to 22 h the percentage of germinated grains increased from 60.0 to 92.3%. At no point of soaking period, 100% germination of bengal gram was recorded. However, there was an increase in percentage of germinated grains from 54.0 to 91.3% with increase in soaking period from 4 to 24 h. Comparing the germinative capacity of wheat and bengal gram it was observed that at each soaking period in response to 24 h of germination, the germinative capacity of wheat was higher than that of the bengal gram (Tables 1, 3).

In bengal gram grains soaked for 4 h and germinated for 24 h the germinated grains with non-measurable sprout length was 29.6% (Table 3). The increase in soaking period from 4 to 14 h did not

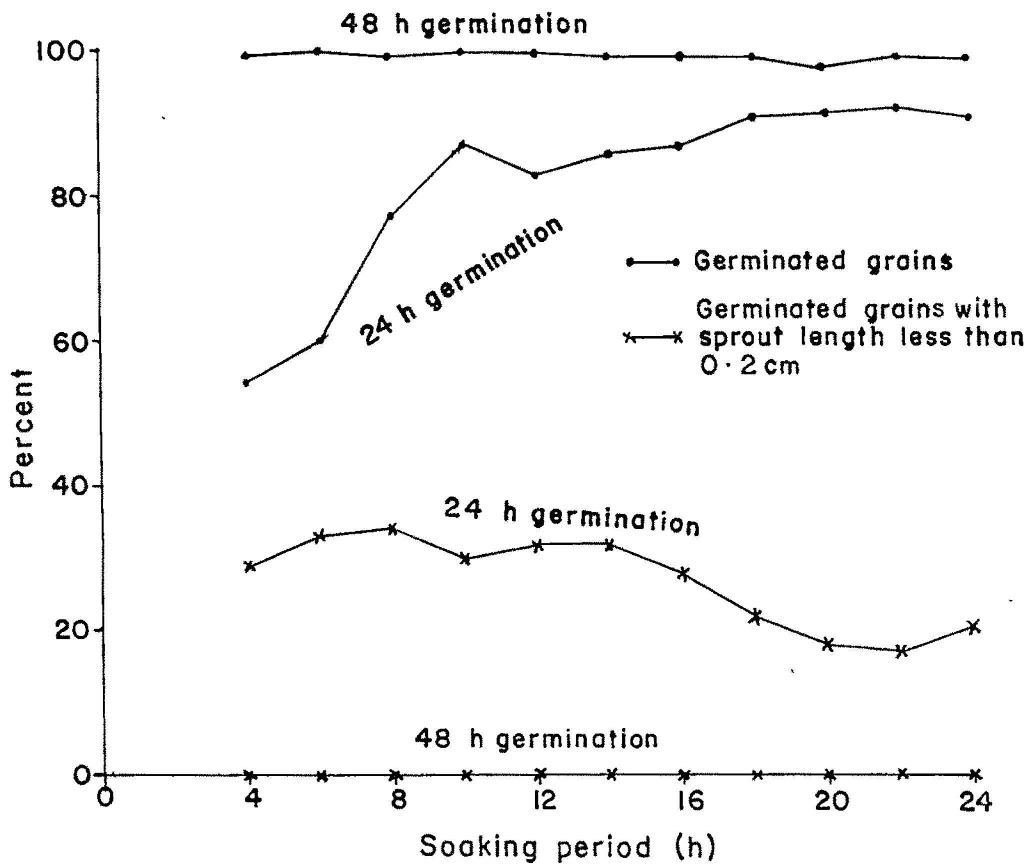
Fig 2. Moisture contents of wheat and bengal gram grains at various soaking periods



markedly decrease the percentage of germinated grains having non-measurable sprout length, it remained between 29.6 and 34.2%. Thereafter, it consistently decreased until 22 h of soaking (Fig 3). About 80% of the 24 h soaked and 24 h germinated bengal gram grains had sprout length more than 0.2 cm. These data also indicatedthat in 24 h germinated grains, the increase in soaking period ffom 4 to 24 h brought about only 10% decrease in percentage of germinated grains having sprout length less than 0.2 cm. In wheat grains, however, the percentage of germinated grains with non-measurable sprout length decreased from 78.7 to 5.3% when the soaking time was increased from 4 to 14 h but no consistant trend was observed after 14 h of soaking period (Table 1). In 4 h soaked bengal gram grains the percentage of germinated grains with non-measurable sprout length was lower than in 4 h soaked wheat grains (29.6 Vs 78.7%) but after 14 h of soaking the percentage of germinated bengal gram grains with non-measurable sprout length was higher than that observed in wheat grains (32.4 Vs 5.3%). This trend that the percentage of bengal gram grains with non-measurable sprout length was higher than that observed in wheat grains persisted when the soaking period was increased from 14 to 24 h.

The mean value for sprout length of bengal gram grains ranged from 0.46 cm to 0.74 cm during the soaking period of 4 to 24 h in response to 24 h of germination (Table 3). Inamdar (1980) had recorded a higher sprout length of 2.1 cm after 12 h of soaking and 24 h of germination.

Fig 3. Germinative capacity of bengal gram grains after 24 and 48 h of germination periods



In response to 48 h of germination period, the germinative capacity of bengal gram grains ranged from 97.7 and 100% on soaking from 4 to 24 h, cent percent germination was observed after 6, 10 and 12 h of soaking. Thereafter, no consistent trend was observed in percentage of germinated grains (Table 4).

Comparing the germinative capacity of grains germinated for 24 and 48 h, soaked for various time periods it was observed that at each soaking period until 24 h of soaking, the percentage of germinated grains was higher after 48 h than after 24 h of germination (Fig 3). Cent percent germination was not observed when the bengal gram grains were soaked for 4 to 24 h and germinated for 24 h.

In response to 48 h of germination all the bengal gram grains had measurable sprout length which meant that 48 h of germination period was advantageous over the 24 h of germination period. The percentage of germinated grains with measurable sprout length which ranged from 66 to 82% after 24 h of germination period became 100% after 48 h of germination period. In wheat grains, after 48 h of germination there were a maximum of 13% grains having non-measurable sprout length but in bengal gram grains irrespective of the soaking period, no grain was found to have non-measurable sprout length.

The mean value for sprout length of 48 h germinated bengal gram grains after 4 h of soaking was 2.21 cm (Table 4). The values ranged from 2.21 to 3.05 cm when the soaking period was increased from 4 to 24 h. Keeping the soaking period constant, the sprout length was 3 to 4 times higher when germination period was increased from 24 to 48 h. In wheat grains, the mean value for sprout length of grains after 48 h of germination ranged from 1.62 to 2.88 cm showing an increase of 1.26 cm over a soaking period of 4 to 24 h. After 24 h of germination, Inamdar (1980) had reported a higher sprout length of bengal gram as that observed in the present study. Likewise, after 48 h of germination, Inamdar (1980) had reported a somewhat higher value of sprout length (3.2 cm) of bengal gram soaked for 12 h than that observed in the present study (3.05 cm).

When the soaking period was increased from 4 to 24 h and the grains were germinated for 48 h, the sprout length increased by 0.84 cm in bengal gram grains and by 1.26 cm in wheat grains (Tables 2, 4). These data indicated that in wheat grains elongation in sprout length was faster in comparison to that in bengal gram grains.

Figures 4 and 5 depict the moisture contents of wheat and bengal gram in relation to their germination capacities. It emerges that the moisture content of about 35% in wheat and of about 54% in bengal gram grains led to 100% germination.

Because 12 h of soaking and 48 h of germination gave 100% germinated bengal gram grains having sprout lengths more than 0.2 cm therefore a germination period of 48 h was considered optimum for bengal gram grains.

Fig 4. The moisture content, and germinative capacity of wheat grains germinated for 48 h

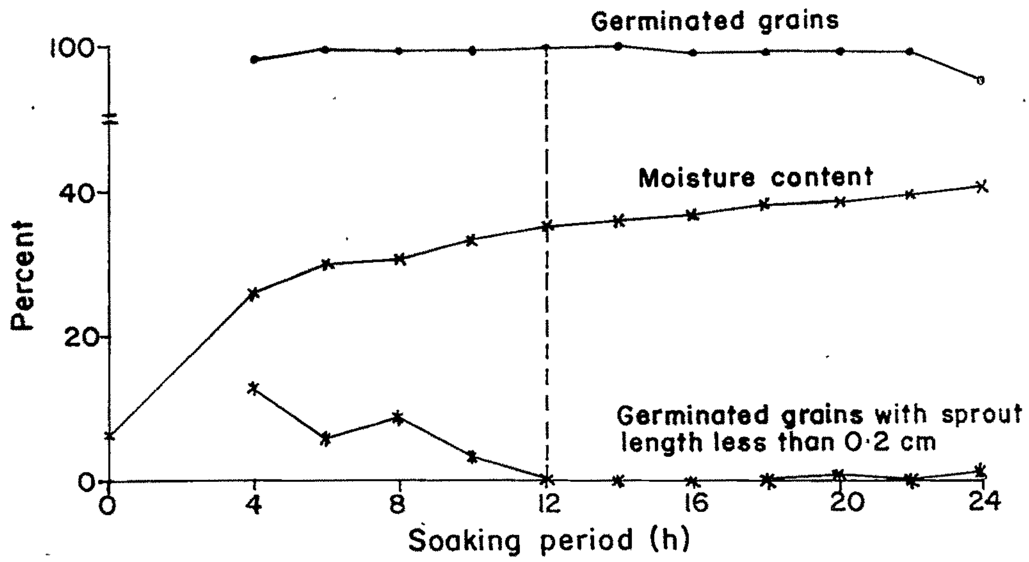
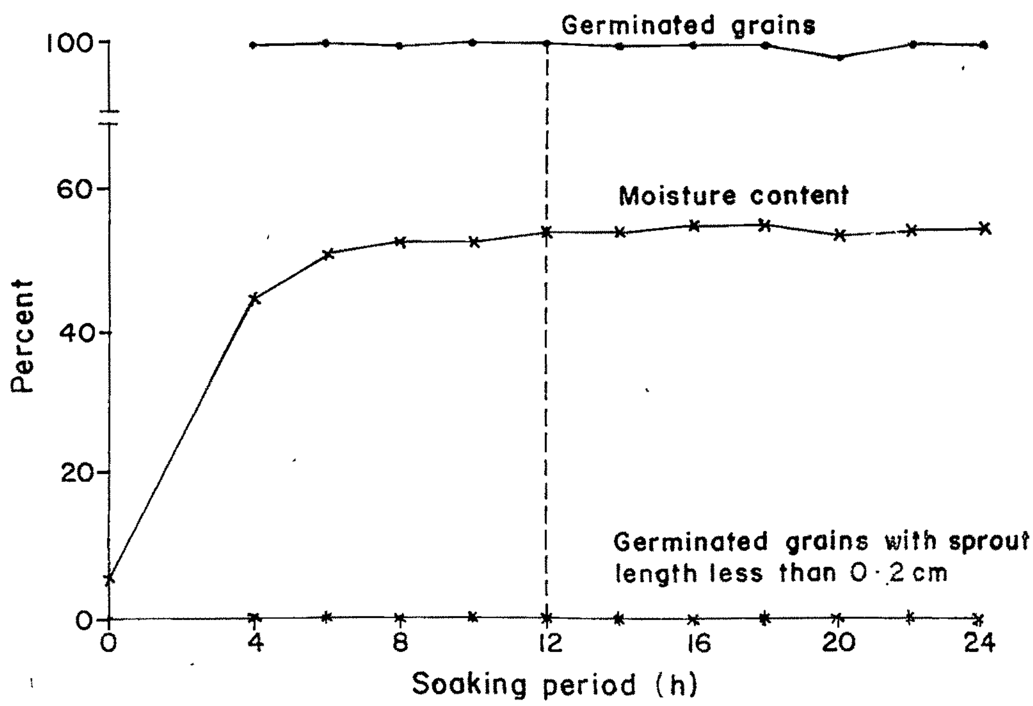


Fig 5. The moisture content, and germinative capacity of bengal gram grains germinated for 48 h



Since after 12 h of soaking and 48 h of germination, both wheat and bengal gram grains had exhibited 100% germination and all the grains had sprout lengths more than 0.2 cm, 12 h of soaking and 48 h of germination were considered optimum for wheat and bengal gram grains.