Moisture movement in cut mature wheat plants

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Muir, W. E., Shrivastava, A. M. and Versavel, P. A. 1989. **Moisture movement in cut mature wheat plants.** Can. Agric. Eng. **31**: 35–38. Moisture transfer through the external surfaces and between the parts of cut, mature wheat plants (moisture content 7–18% wet basis) was measured in a controlled-environment chamber. Moisture adsorption through the outer surface of bare internodes was rapid; equilibrium was reached within about 5 h. Moisture transfer through the lumen and sheared ends was much slower. The leaf sheath had only a slight effect on moisture adsorption by the stem. Nodes did not significantly affect the moisture transfer along the wheat stem. There was moisture movement between the spike and the stem but it was quite small compared with direct transfer between the spike and the surrounding air.

INTRODUCTION

Much of the grain crop on the Canadian Prairies is swathed (windrowed) after reaching physiological maturity. The moisture content of the wheat kernels should be less than 35% (wet mass basis) when it is cut (Dodds 1957). The crop then loses or gains moisture according to the surrounding environmental conditions.

A swathed wheat plant consists of stem (nodes and internodes), leaf (leaf sheath and leaf blade) and spike (kernels, chaff and rachis). The importance to moisture transfer of the different parts of mature wheat plants has not been thoroughly investigated. The objective of the research reported in this paper was to study and compare moisture movement through the external surfaces of plant parts and between plant parts.

MATERIALS AND METHODS

Wheat plants

The crop material was hard red spring wheat (*Triticum aestivum* L. 'Neepawa'). Except for the fresh plants, the plants were grown at the University of Manitoba Experimental Research Station at Glenlea, Manitoba during the summer of 1984. The plants were removed from the swath on the 3rd day after cutting when the kernel moisture content was about 18% (wet basis). The plants were stored in polyethylene bags at about 3°C. The freshly cut plants (cv. Neepawa) used in the desorption experiment were grown in a University of Manitoba greenhouse during spring 1986.

Treatments

To study separately the moisture movement from and through the various plant parts (Table I, Fig. 1) methods of moisture proofing or covering various parts were developed. Six water-resistent materials were tested (Shrivastava 1985). The material chosen to wrap plant parts was thin, laminated sheets of paraffin wax (Parafilm-M, American Can Co., Greenwich, Conn.). The film, which is flexible and self-sealing, could easily be wrapped around stems and spikes and removed after the experiment. Direct moisture movement into the lumen or cut ends of stems was prevented by the application of silicone grease (Dow Corning high vacuum grease). Before using the grease, excess oil was removed by pressing the grease between filter paper for 24 h.

Experimental procedure

For the adsorption treatments (A to M), the required stems and spikes were cut from stored plants. The first internode section was cut from the stem between the spike and first node and the second internode was cut from between the first and second nodes. The five replicates of each treatment consisted of five identical plant parts tied together with wire but with a 1-cm gap between each plant part. The mass of each replicate was measured on an electronic balance (Mettler Model PE-160, 1 mg resolution).

The prepared replicates were stored at 25°C and 38% relative humidity for at least 60 h to reach a uniform initial moisture content. The replicates were then placed in polyethylene bags while the relative humidity of the environmental chamber was increased to 80%. When the relative humidity of the chamber became constant the replicates were placed in single layers on a chamber rack.

The measured temperature of the environmental chamber (Moore Environmental Systems Ltd., Hamilton, Ont.) fluctuated between 24 and 25.5°C in a 9-min cycle. During the adsorption experiments, the relative humidity varied linearly between 72 and 85%, cyclically varying $\pm 2\%$ every 14 s. Horizontal air velocity over the replicates was 0.1–0.2 m/s.

During exposure to moisture adsorption conditions, the replicates were manually weighed on the electronic balance (Mettler Model PE-160) placed in the chamber. These measurements of total mass for each replicate along with the initial moisture content were used to calculate average moisture contents during the experiment. At the end of an experiment the plant parts were unwrapped and the spikes were threshed manually in the chamber. Moisture contents (wet-mass basis) of the straw, chaff and rachis were measured by oven-drying for 24 h at 103°C (ASAE standard for forages, S358.1; American Society of Agricultural Engineers 1985). Moisture contents (wet-mass basis) of the kernels were determined by oven-drying for 19 h at 130°C (ASAE standard S352.1; American Society of Agricultural Engineers 1985).

Two replicates of each treatment N to R were prepared from freshly cut plants and quickly transferred into the environmental chamber to measure desorption. Each replicate was made up of five spikes. The chamber conditions were set at 15°C and 60% relative humidity. The masses of each replicate were recorded continuously by interfacing two balances (Mettler

Table I. Description of treatments

Treatment†	Description
A	Stem internode, 10-cm long, all surfaces exposed
B	Internode, external surface exposed
C	Internode, lumen exposed
D	Internode, sheared end surfaces exposed but lumen closed at both ends
E	Internode with leaf sheath exposed
F	Internode with leaf sheath removed and external surface exposed
G	Covered internode, 10-cm long with one node and 2.5 cm stub of stem exposed
H	Internode, 10-cm covered, grease plug replacing node and 2.5 cm of stem exposed
I,O	Spike and 10-cm stem all surfaces exposed
J,P	Spike covered and 10-cm stem exposed
K,Q	Spike exposed and 10-cm stem covered
L	Spike covered, no stem, sheared end exposed
M,R	Spike exposed, no stem
N	Spike and 10-cm stem all surfaces covered

†Treatments A to M were stored cut wheat plants exposed to adsorption conditions. Treatments N to R were freshly-cut wheat plants exposed to desorption conditions.

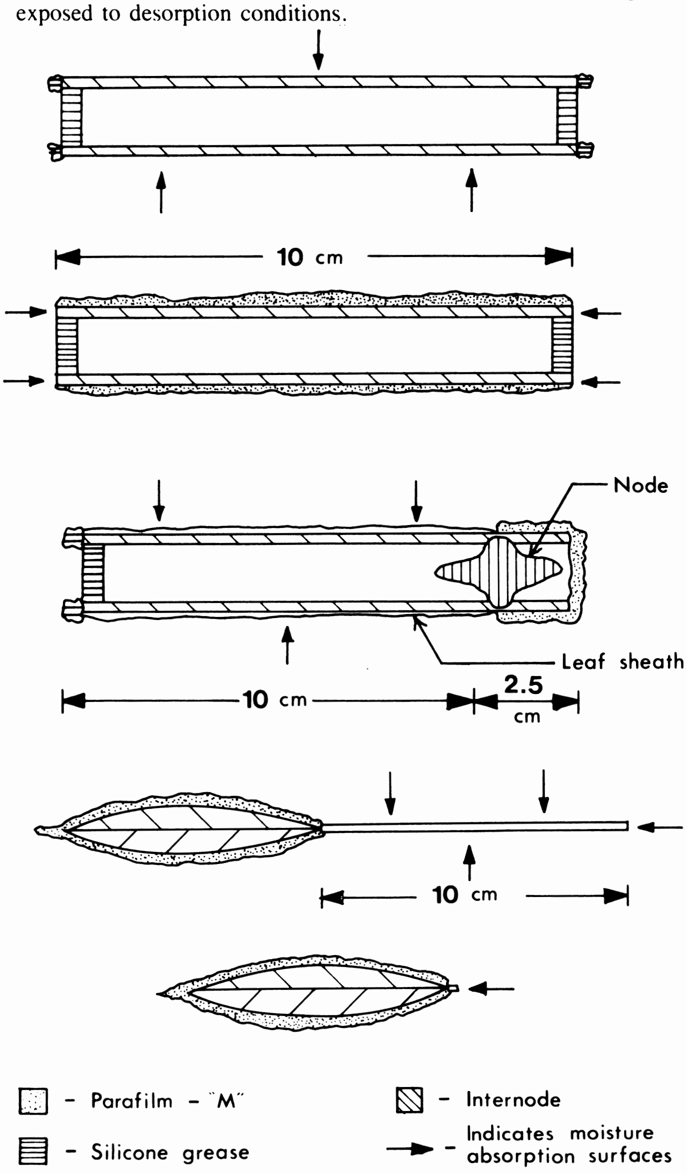

Fig. 1. Schemata of selected treatments designated from top to bottom: B, D, E, J and L.

PE1600, resolution 0.01 g) with two portable computers (TRS-80 Model 100, Tandy Corp.).

RESULTS AND DISCUSSION

Adsorption through stem surfaces

Moisture adsorption into straw stems occurred most rapidly through the outer surface of the stems (treatment B, Fig. 2). Equilibrium was reached within 4–5 h through this surface compared with over 60 h through the lumen (treatment C) or cut ends (treatment D). For both internodes moisture contents of treatments A and B were significantly different ($P < 0.05$) from those of treatments C and D at exposure times of 1, 4, 7 and 10 h. At the six exposure times statistically analyzed (1, 4, 7, 10, 24 and 60 h) moisture contents of the first internodes for treatments A, C and D were significantly different (lower) than those for the second internodes. The mean difference between internodes for these three treatments increased from 0.8% at 0 h to 2.0% at 7 h, 2.9% at 24 h and 2.4% at 60 h. Mean moisture contents of treatment B were not significantly different for the two internodes.

Adsorption through leaf sheath

The leaf sheath significantly affected the moisture adsorption into the straw stem only at exposure times of 60 h for the first internode and 4, 7 and 10 h for the second internode. But the maximum differences in moisture contents were relatively small. For the first internode at 60 h of exposure the stems with the leaf sheath (treatment E) had a moisture content of 18.5% ±0.46 while the stems without a leaf sheath (treatment F) had a moisture content of 20.4% ±0.55 (i.e., a difference of 1.9%). For the second internode the maximum difference was 1.4% at 4 h.

Moisture movement through stem nodes

Neither the first nor the second node significantly restricted movement of moisture along the straw stem. For example, moisture contents (means of five replicates ± standard deviation) at selected times of exposure for the first node were: 0 h, 6.1% for both treatments; 6 h, 8.4% ± 0.08 for treatment G (with node) and 8.8% ±0.31 for treatment H (with grease

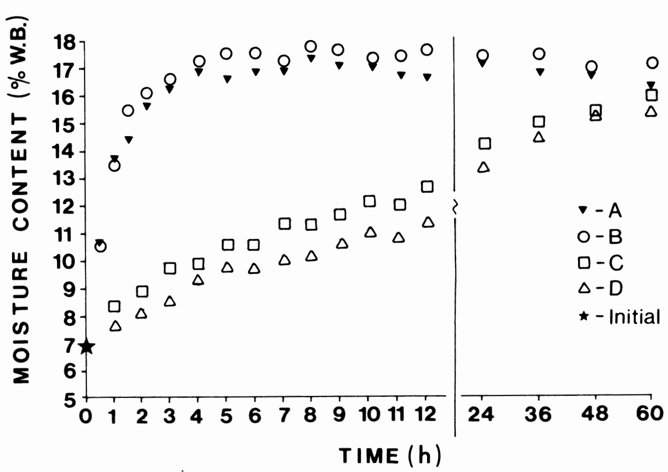

Fig. 2. Moisture adsorption by the second internode of mature wheat plants exposed to 25°C and 80% relative humidity. (Each point was a mean of five replicates, each replicate consisted of five plant stems.)

plug node); 24 h, 10.4% ±0.17 for G and 10.6% ±0.44 for H; and 60 h, 12.8% ±0.32 for G and 12.1% ±0.66 for H.

Moisture exchange between spike and stem

Covered spikes (treatments J and L) gained moisture relatively slowly compared with exposed spikes (treatments I, K and M, Fig. 3). Kernels in the covered spike, treatment J, increased only 0.7% in moisture content above the initial content of 11.2% during 96 h of exposure. Kernels from the exposed spike and stem had an increase in moisture content of 7.1%. The total amount of moisture adsorbed through the exposed, 10-cm length of straw in treatment J was about three times greater than that into stems only (treatment B) because some moisture moved from the stems into the covered spikes.

Moisture adsorption into exposed spikes without stems (treatment M) was similar to that for spikes with stems (I, Fig. 3). Exposed stems 10 cm long did not appear to greatly increase moisture adsorption and movement into covered spikes (J and L, Fig. 3). Moisture moved from exposed spikes into covered stems (K) but the moisture content of the covered stems after 96 h was less than exposed stems (I and J) by a difference of 4.0%.

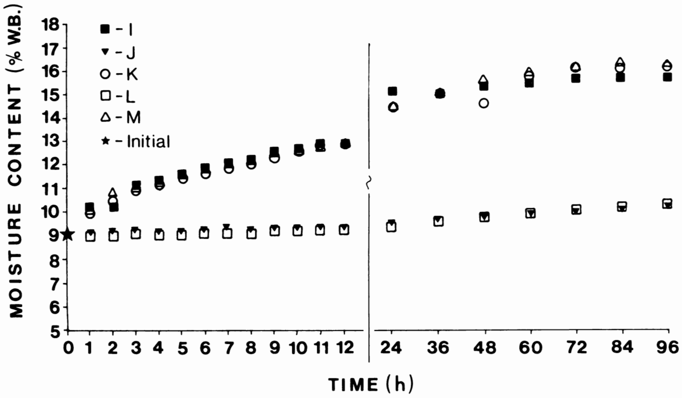

Fig. 3. Moisture adsorption by wheat spikes and first internodes exposed to 25°C and 80% relative humidity. (Each point was a mean of five replicates, each replicate consisted of five plant parts.)

Moisture transfer from fresh spikes and stems

Under moisture desorption conditions moisture moved from covered spikes out through exposed stems (treatment P, Fig. 4) but at a slow rate compared with exposed spikes (treatments O, R and Q). This limited moisture exchange between spike and stem was similar to the movement of moisture from stem to spike in old, cut plants exposed to readsorption conditions (treatment J, Fig. 3). Exposed spikes with and without stems had the same rates of desorption (O, Q and R, Fig. 4).

CONCLUSIONS

Moisture transfer experiments with mature wheat plants cut and stored at a low moisture content were good indicators of results obtained with freshly-cut plants. Thus, similar research can be extended throughout the year rather than concentrated at harvest time.

Moisture movement between wheat straw and its surroundings was mainly through the exterior surface. The effect of the leaf sheath was statistically significant under some conditions, but the magnitudes of the differences were small. Thus, little or no benefit in drying would be gained by designing a swather that removed the leaf sheath.

Nodes in the stem did not cut off moisture movement in the mature plant stem. Moisture may move upward through the stem from wet soil; however, this movement may be small compared with adsorption from surrounding humid air.

Spikes dried or rewetted mainly through their external surfaces; thus separating spikes from cut or standing stems has no direct effect on kernel moisture contents. More important variables affecting moisture exchange of maturing and drying grain crops are relative humidity, temperature and movement of air surrounding the spikes.

ACKNOWLEDGMENTS

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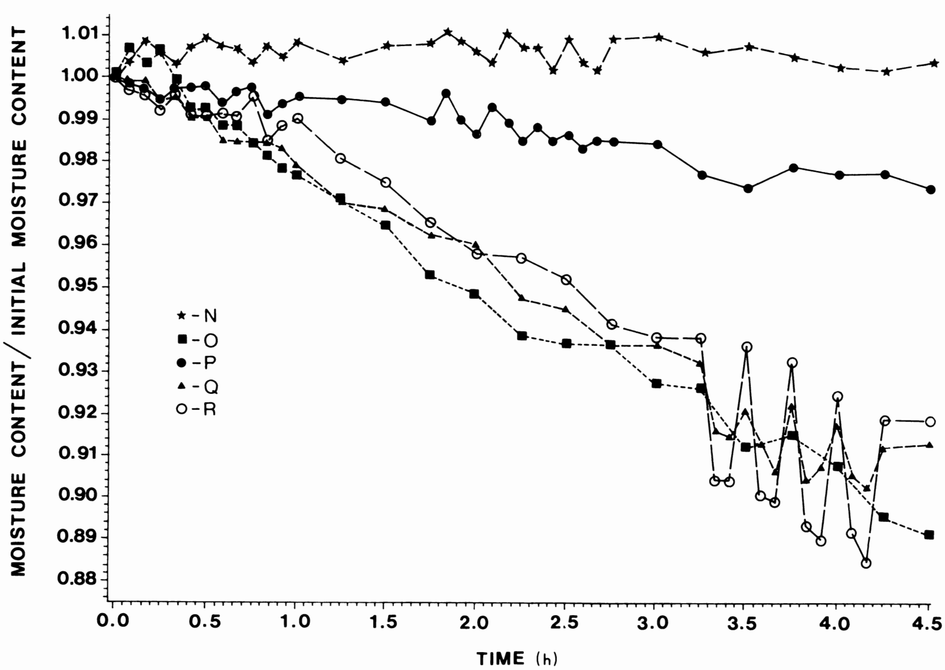

Fig. 4. Moisture desorption of freshly cut wheat spikes and stems exposed to 15°C and 60% relative humidity.

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