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Relationships between sprouting characters and stem development in two maincrop potato varieties

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Summary

Two experiments, which are described, examined the relationships between three sprouting characters visible on the seed tubers before planting and the number of stems produced by those tubers. The varieties used produced extensive sprout development at the apical eye complex and more than one stem was produced from a single bud position. Good linear relationships were established between the number of stems produced by each tuber and the number of 'sproutlets' on the tuber before planting.

Introduction

The stem is now generally accepted as the unit of population in the potato crop (Jarvis, 1971) but accurate control of the number of stems in the field requires the establishment of precise relationships between seed tuber characters visible before planting and the number of stems actually produced by each seed tuber.

Reestman & de Wit (1959) found a linear relationship between the surface area of the seed tuber and the number of main stems in the crop, while Bleasdale (1965) reported that a constant proportion of the eyes of Majestic sprouted and that the number of main stems in the field was directly proportional to the number of sprouts. He concluded that the number of main stems was directly proportional to the number of eyes per set. However Schepers & Hoogland (1968) pointed out that the number of sprouting eyes depended upon variety, storage method and treatment before planting and concluded that it was not reasonable to base the spacing distance on the total number of sprouts. Instead they reported that those sprouts showing root primordia gave a good estimate of the main stem population. This is sensible because Morris (1967) showed that the sprouts actually growing at planting were the only ones to emerge as stems.

This use of the term sprout is very common amongst research workers, yet there have been few attempts at its definition and it seems likely that a range of interpreta-

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tions are used. Bates (1935) described a sprout as 'an eye showing visible sprouts' while Moorby (1967) called sprouts 'the lateral shoots on the tuber at planting'. He realized the possible confusion of terminology and referred to Rieman et al. (1953) and Svensson (1962) whom he considered to have used the term stem to mean what he called a sprout.

Milthorpe (1963) pointed out that second order lateral buds also subtended axillary bud development which could be regarded as a tertiary vegetative axis. These axillary buds rarely develop but those around the apical bud frequently do so (Wurr, 1971) and when reasonably developed are, in some varieties, impossible to distinguish from the branches of the apical bud itself. Thus the use of the term sprout is subjective and confusion is likely to occur especially where comparisons are made between contrasting varieties.

The studies reported here were made in an attempt to rationalize the definitions of sprouting characters and their relationships to the stem populations produced.

Experiments

Experiments were carried out in 1970 at the Norfolk Agricultural Station, Morley St. Botolph on a sandy loam of the Ashley series and in 1971 at Cambridge on a gravelly loam of the Milton series.

In 1970 (Experiment I) there were eighteen treatments consisting of all combinations of the two varieties Pentland Crown and Maris Piper, three seed sizes (32–35, 41–45 and 51–57 mm) and three spacings (22.1, 27.9 and 46.2 cm) arranged in two randomized blocks. Plots were split into sub-plots for sequential harvesting at fortnightly intervals. Full experimental details are reported elsewhere (Wurr, 1974).

Once grown seed from the Morley Farm was riddled into the three required grades in January 1970 and was trayed up and chitted in a potato store at ambient air temperature until planting on 30 April and 1 May. At planting, samples of 100 tubers of each type were retained for the determination of growing points, sprouts and 'sproutlets'. These were defined as follows: *Growing point:* Any position on the tuber at which active bud growth occurred. However, more than one bud per eye was regarded as one, except at the apical complex where buds that were clearly separate were counted as individual growing points. This concept was used to give an indication of the number of separate positions at which bud growth occurred, in relation to the number of those positions likely to bear stems. The restriction to only one growing point per eye, except at the apical complex, was used because although most eyes contain up to three buds, normally only one of these produces stems (Gray & Bleasdale, 1971) while in the apical complex several buds may produce stems (Wurr, 1971). *Sprout:* Bud development on the seed tuber which had leaf initials present and at least partly open. Numbers greater than one per eye were regarded as one except at the apical complex where sprouts were counted as individuals if they were definitely derived directly from the seed tuber.

'*Sproutlet*': Bud development on the seed tuber which had leaf initials present and at

least partly open, irrespective of whether it was derived directly from the seed tuber or whether it was a sprout branch.

The restriction to one sprout per eye, except at the apical complex, was imposed for the same reasons as a similar restriction with growing points and the specification of direct derivation from the seed tuber was to avoid inclusion of branches derived from the same growing point. However the term 'sproutlet' was not subject to these restrictions and therefore included all bud growths which showed sufficient morphological development irrespective of their derivation.

The number of above-ground stems per tuber was counted in the field at each harvest and in addition the number of stem sites was counted at harvests 1–3. A stem site was defined as a point on the seed tuber from which a main stem or main stems were derived and was observed by digging up the growing plant and detaching the stems from the parent tuber.

Main stems grow directly from the seed tuber (Krijthe, 1955) while above-ground stem counts include both main stems and secondary branches. However numbers of main stems and above-ground stems are generally very similar (Allen & Wurr, 1973) and except where otherwise stated the term 'stems' in these experiments refers to above-ground stems.

In 1971 (Experiment II) the treatments were all combinations of the same two varieties and three seed sizes as used in 1970 together with three planting treatments: unsprouted seed planted on 31 March and harvested on 29 April, unsprouted seed planted on 31 March and harvested on 22 July and sprouted seed planted on 29 April and harvested on 22 July. In this paper only the results from the last treatment are considered. Treatments were arranged in a randomized block design with two replicates. Further experimental details are reported elsewhere (Allen & Wurr, 1973).

Foundation Stock Scottish seed was imported in early March and showed considerable sprout growth by planting on 29 April. Counts of growing points, sprouts and 'sproutlets' were made on samples of 48 tubers per treatment prior to planting and the number of stems and stem sites per tuber were determined when the plants were harvested.

Results

Experiment I 1970

The number of growing points, sprouts, 'sproutlets', stem sites and the mean number of stems per tuber for each category of seed are shown in Table 1. The counts of growing points and sprouts were difficult with the two varieties used because of the problem of identifying individual points of attachment to the tuber where extensive sprout development occurred (Fig. 1).

The counts of all the variables measured increased with seed size in both varieties but there was a good linear relationship only between the number of stems per tuber and the number of 'sproutlets' per tuber (Fig. 2).

Table 1. The number of growing points, sprouts, 'sproutlets', stem sites and above-ground stems per tuber, 1970.

Variety[1]	Seed size[2] (mm)	Growing points[3]	Sprouts[4]	Sproutlets[5]	Stem sites[6]	Above ground stems[7]
Pentland Crown	32–35	4.2	1.8	2.1	1.7	2.4
	41–45	4.8	2.2	3.2	2.2	3.5
	51–57	4.8	2.4	4.2	2.5	5.1
Maris Piper	32–35	3.9	2.5	3.1	1.7	3.1
	41–45	4.5	2.9	3.7	1.8	4.3
	51–57	5.0	3.1	5.0	2.2	6.4

[1] *Sorte – Variété;* [2] *Pflanzknollengrösse – Grosseur de plant;* [3] *Keimansätze – Points de croissance;* [4] *Keime – Germes;* [5] *Einzelkeime – Petits germes;* [6] *Stengelansatzstelle – Emplacements de tiges;* [7] *Oberirdische Stengel – Tiges au-dessus du sol*

Tabelle 1. Anzahl der Keimansätze, Keime, Einzelkeime, Stengelansatzstellen und Stengel pro Knolle, 1970.

Tableau 1. Nombre de points de croissance, de germes, de petits germes, d'emplacements de tiges et de tiges par tubercule, 1970.

Experiment II 1971

Counts of growing points and sprouts again gave a poor indication of the number of stems produced (Table 2) but there were good separate linear relationships between the number of stems per tuber and the number of 'sproutlets' per tuber, for each variety (Fig. 3).

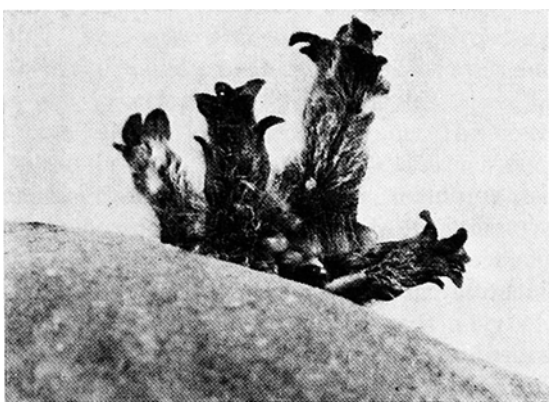

Fig. 1. Extensive sprout development at the apical complex, showing four 'sproutlets' (cv. Pentland Crown).

Abb. 1. Starke Keimentwicklung am Kronenende, das vier Einzelkeime (Sproutlets) aufweist (Sorte Pentland Crown).

Fig. 1. Développement extensif de germes du complexe apical, montrant quatre 'petits germes' (var. Pentland Crown).

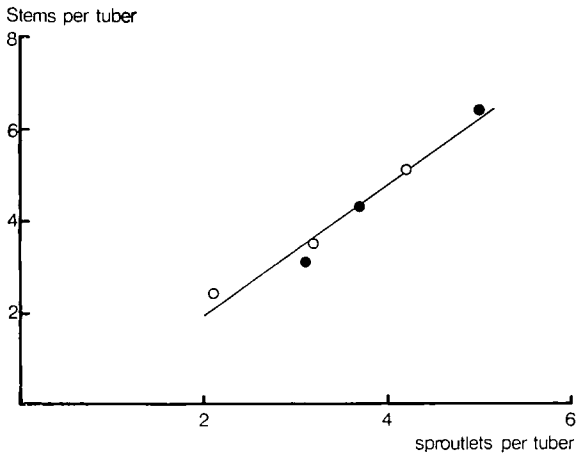

Fig. 2. The relationship between the number of above-ground stems per tuber and the number of 'sproutlets' per tuber, 1970.

Stems per tuber – *Stengel pro Knolle – Tiges par tubercule*
Sproutlets per tuber – *Einzelkeime pro Knolle – 'Petits germes' par tubercule*
o Pentland Crown; • Maris Piper; $y = 1.43x - 0.95$ ($R^2 = 0.97$).
Abb. 2. Verhältnis zwischen der Anzahl der oberirdischen Stengel pro Knolle und der Anzahl der Einzelkeime pro Knolle, 1970.
Fig. 2. Relation entre le nombre de tiges au-dessus du sol par tubercule et le nombre de 'petits germes' par tubercule, 1970.

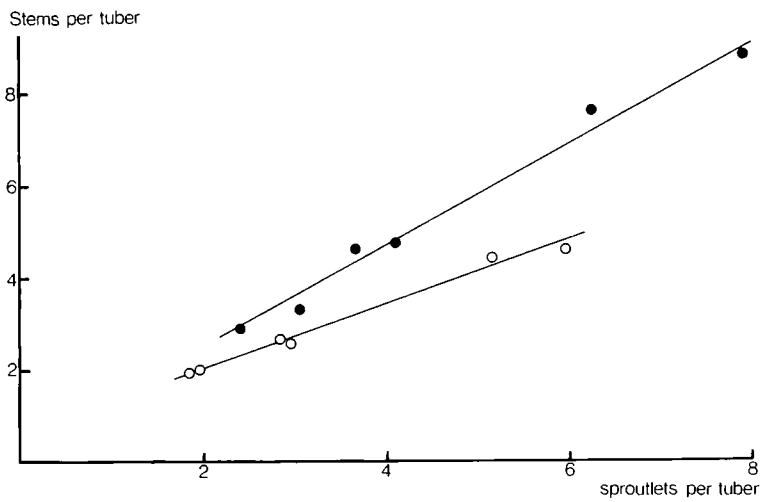

Fig. 3. The relationship between the number of above-ground stems per tuber and the number of 'sproutlets' per tuber, 1971.

o Pentland Crown; $y = 0.68x + 0.70$ ($R^2 = 0.99$); • Maris Piper; $y = 1.12x + 0.24$ ($R^2 = 0.99$).
Siehe Uebersetzungen bei Abb. 2 – Voir fig. 2 pour les traductions
Abb. 3. Verhältnis zwischen der Anzahl der oberirdischen Stengel pro Knolle und der Anzahl der Einzelkeime pro Knolle, 1971.
Fig. 3. Relations entre le nombre de tiges au-dessus du sol par tubercule et le nombre de 'petits germes' par tubercule, 1971.

Table 2. The number of growing points, sprouts, 'sproutlets', stem sites and above-ground stems per tuber, 1971.

Variety[1]	Seed size[2] (mm)	Growing points[3]	Sprouts[4]	'Sproutlets'[5]	Stem sites[6]	Above ground stems[7]
Pentland Crown	32–35	4.3	1.4	1.9	1.3	2.0
	41–45	5.2	2.0	2.9	1.6	2.6
	51–57	5.5	2.8	5.6	2.1	4.5
Maris Piper	32–35	3.7	1.9	2.7	1.8	3.1
	41–45	4.0	2.0	3.9	1.7	4.7
	51–57	4.3	2.8	7.1	2.5	8.2

[1–7] *Siehe Tabelle 1 – Voir tableau 1*

Tabelle 2. Anzahl der Keimansätze, Keime, Einzelkeime, Stengelansatzstellen und Stengel pro Knolle, 1971.

Tableau 2. Nombre de points de croissance, de germes, de petits germes, d'emplacements de tiges par tubercule, 1971.

Discussion

The definitions of the terms growing point and sprout were deliberately chosen to give an estimate of the number of the stems produced. However they were of little value in either experiment because determination of individual points of attachment to the parent tuber was difficult owing to extensive sprout development at the apical complex in both varieties. It was therefore not possible to use the definition of sprouts showing root primordia as suggested by Schepers & Hoogland (1968). Counts of growing points and sprouts might nevertheless be of greater value with varieties like King Edward and Craig's Royal which develop more distinct eyes and sprouts.

It is interesting that in both years there were more growing points than stems and more stems than stem sites. This supports Morris (1967) who said that only those sprouts growing at planting develop into stems and shows that with the varieties used here, more than one stem was produced from a single bud position. Allen & Wurr (1973) reported that this development resulted in the majority of above ground stems originating from a mass of tissue at the apical end of the seed tuber, while the remainder developed from eyes away from the apical complex. This suggests that the measurement of 'sproutlets' which took account of extensive sprout branching at the apical complex, ought to give a good indication of the number of stems produced and Fig. 2 confirms this. However Fig. 3 showed that there were good separate relationships between the number of stems per tuber and the number of 'sproutlets' per tuber for each variety. Closer examination of Fig. 2 reveals a similar tendency towards separate relationships but there were insufficient degrees of freedom available to carry out such linear regressions satisfactorily. In view of well established varietal differences in sprouting behaviour and the number of stems produced it seems sensible that there should be separate regression lines for each variety though Schepers &

Hoogland (1968) reported no such distinction.

The gradients of both lines in 1971 were less than that of the combined regression in 1970 so that the value of the relationships for predictive purposes is limited. However there are good reasons why the gradients in the two years should differ because the seed was from widely differing sources and was subjected to completely different storage regimes. Further investigation of stem development clearly needs to be carried out for individual varieties, with a range of seed sizes and taking into account such factors as the origin and storage environment of the seed.

Common understanding of basic tuber characteristic definitions is obviously desirable and it is suggested that the use of the term 'sproutlet' as defined here will give a good indication of the number of stems produced by a tuber.

Acknowledgments

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Zusammenfassung

Zusammenhang zwischen Art der Keimung und Stengelentwicklung bei zwei Speisekartoffelsorten

Die Versuche, von denen hier berichtet wird, wurden angestellt in der Absicht, die Definition der Keimungsarten und ihr Zusammenhang mit der Anzahl der erzeugten Stengel wissenschaftlich zu begründen. In beiden Jahren wurden drei Pflanzgutgrössen der frühen Speisekartoffelsorten Pentland Crown und Maris Piper verwendet, und es wurden Zählungen von drei Arten der Keimung, wie sie sich an der Knolle vor dem Auspflanzen zeigen, vorgenommen und wie folgt definiert:

Keimansatz: Jede Stelle an der Knolle, an welcher aktives Knospenwachstum vorkam, wobei mehr als eine Knospe pro Auge als eine einzige gezählt wurde, ausgenommen am Kronenende.

Keim: Keimentwicklung an der Knolle mit Ansatz von Blättchen, die mindestens teilweise geöffnet sind. Beim Vorkommen von mehr als einer Knospe pro Auge wurde dies nur als ein Keim gezählt, ausgenommen am Kronenende, wo alle direkt aus der Knolle stammenden Keime einzeln gezählt wurden.

Einzelkeime: Knospenentwicklung an der Knolle mit Ansatz von Blättchen, die mindestens teilweise offen sind, unabhängig davon, ob die Knospe direkt aus der Knolle stammt oder ob es eine Triebverzweigung war.

Diese Eigenschaften wurden dann mit der Anzahl Ansatzstellen der einzelnen Triebe an der Mutterknolle und der Anzahl der von jeder Knolle erzeugten Stengel (Tabellen 1 und 2) in Zusammenhang gebracht.

Zählungen von Keimansätzen und Keimen waren in beiden Jahren infolge starker Keimentwicklung (Abb. 1) am Kronenende bei beiden Sorten von geringem Wert. Im Jahre 1970 jedoch gab es einen guten allgemeinen Zusammenhang zwischen der Anzahl Stengel und der Anzahl Einzelkeime (sproutlets) pro Knolle (Abb. 2), und 1971 bestanden für jede Sorte (Abb. 3) gute lineare Zusammenhänge. Angesichts der deutlich nachgewiesenen sortenbedingten Unterschiede im Keimverhalten und in der Anzahl der erzeugten Stengel scheint es logisch, dass sich solche Zusammenhänge entsprechend der Sorte unterscheiden sollten. Es ergaben sich auch Unterschiede im Grad der Uebereinstimmung in den beiden Jahren. Es wurde angenommen, dass diese auf die Verwendung von Pflanzgut von verschiedenen Herkünften und Lager-

bedingungen zurückzuführen sind. Weitere Untersuchungen der Stengelentwicklung aus der Pflanzknolle müssen offenbar an einzelnen Sorten durchgeführt werden, wobei Faktoren, wie Herkunft und vorangegangene Lagerung des Pflanzgutes, in Betracht zu ziehen sind.

Es wird angenommen, dass die Verwendung der Bezeichnung Einzelkeim (sproutlet), wie sie hier definiert wurde, einen guten Hinweis auf die Anzahl der von einer Knolle erzeugten Stengel gibt.

Résumé

Relation entre les caractères de germination et le développement des tiges dans deux variétés de grande culture

Les études rapportées ici ont été faites dans le but de rationaliser les définitions des caractères de germination et leurs relations avec le nombre de tiges produites. Au cours de chacune des deux années, on a effectué des comptages sur trois caractères de germination du tubercule avant la plantation, en utilisant trois grosseurs de plants des variétés précoces de grande culture Pentland Crown et Maris Piper; ces caractères de germination sont les suivants:

point de croissance: en quelque position sur le tubercule qu'apparaisse une croissance active de bourgeon, on n'a considéré comme une unité plusieurs bourgeons par oeil, sauf dans le complexe apical.

germe: bourgeon en développement sur le tubercule avec feuilles naissantes qui sont ouvertes au moins partiellement. Des nombres supérieurs à 1 par oeil sont ignorés sauf dans le complexe apical où les germes provenant directement du tubercule sont comptés individuellement.

petit germe (sproutlet): bourgeon en développement sur le tubercule qui a des feuilles naissantes, qui sont au moins partiellement ouvertes, sans tenir compte s'il provient directement du tubercule ou s'il constitue une branche d'un germe. Ces caractères sont alors comparés au nombre d'emplacements de tige (points individuels d'attache de tige sur le tubercule parental) et au nombre de tiges produites par chaque tubercule (tableaux 1 et 2).

Dans les deux variétés, les comptages des points de croissance et des germes sont de peu de valeur dans l'une ou l'autre année en raison du développement extensif des germes (fig. 1) au complexe apical. Toutefois en 1970, une bonne relation se révélait entre le nombre de tiges et le nombre de 'petits germes' par tubercule (fig. 2), et, en 1971, il apparaissait de bonnes relations linéaires pour chaque variété prise séparément (fig.3). Pour bien établir les différences variétales dans le comportement à la germination et le nombre de tiges produites, il semble raisonnable d'admettre que de telles relations puissent varier avec les variétés. Il apparaît aussi des différences dans les gradients des lignes dans les deux années et on considère que ces différences sont dues à l'utilisation de plants de diverses origines et conditions de stockage. De nouvelles recherches sur le développement des tiges à partir du plant doivent absolument porter sur des variétés individuelles, en tenant compte de facteurs tels que l'origine et la rétrospection des conditions de conservation.

Il est supposé que l'usage du terme 'petit germe', tel qu'il est défini ici, donne une bonne indication du nombre de tiges produites par un tubercule.

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