Journal of Applied Horticulture, 13(2): 108-114, 2011

Application of extended BBCH scale for phenological studies in mango (*Mangifera indica* L.)

Shailendra Rajan*, Divya Tiwari, V.K. Singh, Pooja Saxena, Shilpi Singh, Y.T.N. Reddy[1], K.K. Upreti[1], M.M. Burondkar[2], A. Bhagwan[3] and Richards Kennedy[4]

*Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow. [1]Indian Institute of Horticultural Research, Bangalore. [2]Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra. [3]Fruit Research Station, Sangareddy-Medak, Andhra Pradesh. [4]Floriculture Research Station, Thovalai, Tamil Nadu, India. *E-mail: srajanlko@gmail.com*

Abstract

Phenological studies are important for understanding the influence of weather dynamics on vegetative growth, flowering and fruiting on mango. BBCH (Biologische Bundesantalt, Bundessortenamt and Chemische Industrie) scale was used for data recording and to assess utility of the scale in mango phenological studies. Phenological stages of the mango were recorded at weekly intervals on 60 shoots of cultivar Totapuri at five diverse locations for testing usefulness of scale under different diverse ecologies and data from one location, *i.e.,* Lucknow (26º 54´ N and 80º 48´ E) was used for analysis. Existing BBCH scale was modified on the basis of data recorded for mango in which seven out of 10 principal stages were used, starting with bud development (stage 0) and ending with maturity of fruit (stage 8). Three digit scale was used for inclusion of the mesostages between the principal and secondary growth stages. Highly recurring flowering phenophases were 511 (18 %), 513 (20 %) recorded in standard week 9 and 517 (45 %) in standard week 11 (March). Other important phenophases, 619 (38 %) and 709 (10 %) occured during standard weeks 13 and 22 to 23, respectively. A high degree of variation in shoots representing principal growth stages *viz.*, vegetative bud, leaf and shoot development was observed due to simultaneous transition of the stages during standard week 33 to 42 and 4 to 24. Limitations of existing BBCH scale and comprehended modifications have been proposed and discussed. The study revealed that the extended BBCH–scale for mango can be widely used because of its utility in describing all phenophases pertaining to bud, shoot, leaf, panicle and fruit development and indicated the incisive growth pattern of the shoots and seasonal variation. This is the first report on quantitative analysis of mango phenological data using BBCH scale.

Key words: BBCH scale, Biologische Bundesantalt, Bundessortenamt and Chemische Industrie, mango, phenology, phenophase, flowering, growth

Introduction

Phenological studies aim on the periodicity in the life-cycle events of plants and are influenced by seasonal variations owing to weather factors mainly temperature and precipitation. In fact, changes in the time of phenophases of fruit trees are of great economical importance because they have direct impact on factors influencing final fruit yield (Kushwaha and Singh, 2008). Phenological studies in mango are also important for planned management of orchards and alerting mango growers against environmental vagaries. It is also useful for understanding the phenological impacts during the flowering phase and the subjacent effects on other phenological events. Researchers have emphasized significant role of these studies in highlighting common trends in mango phenology along with regional and varietal differences in response to recent climatic changes (Schnell and Knight, 1998) and understanding the differential trends in main and off-season varieties.

Till eighties, there was no homogeneous coding method to describe developmental stages of the major cultivated plants and phenological stages were usually characterized using a combinations of letter and numbers. Fleckinger (1948) evolved a scale for fruit trees which does not fulfil the requirements of a growth scale and mainly describe inflorescence and not the bud, leaf and shoot development. Another scale proposed by Aubert and Lossois (1972) focused only on shoot and panicle development. These scales do not define the complete flowering and fruit development cycles by using numerical codes. Zadoks *et al.* (1974) published the first decimal code to standardize the description of homologous developmental stages of different crops using standard codes. A further development in phenology recording methodology is BBCH-scale (BBCH = Biologische Bundesantalt, Bundessortenamt und Chemische Industrie) proposed by Bleiholder *et al.* (1989) and the extended BBCH-scale proposed by Hack *et al.* (1992). The advantage of the BBCH scale is its simplicity and ease of use for annual, biennial and perennial plants and it also describes both the vegetative and reproductive stages of plant growth. Since then, BBCH-scale has been widely accepted for use in cereals, colza, bean and sunflower (Lancashire *et al.*, 1991), beet (Meier *et al.*, 1993) and potato (Hack *et al.*, 1993). Thereafter, some researchers made BBCH based scales for pome and stone fruit trees (Meier *et al.*, 1994), grapevine (Lorenz *et al.*, 1994), various vegetables (Feller *et al.*, 1995a; 1995b) and fruit crops, *viz.*, pomegranate (Melgarejo *et al.*, 1997), citrus (Augusti *et al.*, 1997), loquat (Martinez-Calvo *et al.*, 1999), olive (Sanz-Cortés *et al.*, 2002) and persimmon (García Carbonell *et al.*, 2002). A notable effort was made to study the utility of BBCH scale for mango phenology (Hernández *et al.*, 2010).

Mango, a fruit tree species grown in both subtropics and tropics, demonstrates substantial seasonality in flowering, fruiting, leaf-flushing events (Parrado-Rosselli *et al.*, 2006) and follows a phenological cycles of 12 months in subtropical regions. However, two or more peaks in phenophases are possible in the tropics because the sun passes overhead twice each year, influencing insolation rates and weather patterns (Anderson *et al.*, 2005). Phenology has emerged as an important integrative measure to assess the impact of climate change on horticultural crops like mango, which is substantially sensitive to weather dynamics. Keeping above facts in view, the phenological studies were conducted to assess BBCH-scale for mango and also demonstrate the information which can be generated from data collected with application of the scale.

Materials and methods

Location and plant material: Phenological data was collected at five diverse eco-geographical locations *viz.*, Lucknow (subtropics, hot subhumid (dry) eco-region), Bangalore (Central Karnataka Plateau, hot moist semi-arid), Kanyakumari (Hot subhumid to semi-arid eco-region), Medak (Hot semi-arid ecoregion) and Dapoli (West coast Ghat region). Multilocational information was collected for accessing the suitablility of scale for describing phenological pattern under diverse mango growing conditions. Data collected at Lucknow, located at 26° 54´ N and 80° 48´ E was used for analysis and interpretation. Totapuri, being a variety with wider adaptability, was used for data collection on 25 years old trees (3 trees) at weekly intervals on 60 shoots tree^{-1} (15 shoots tagged in each direction).

Scale: Developmental stages and morphological characteristics were recorded as per BBCH scale. Representative shoot parts were coded as per primary and secondary phenological growth stages and photographed for recorded information. Due to inclusion of the mesostages between the principal and secondary growth stages, three digit scale was used to study the mango phenology.

The existing BBCH scale (Hernández *et al.*, 2010) was used for the entire developmental cycle of mango and was subdivided into seven clearly recognisable and distinguishable principal growth stages out of 10 of general BBCH scale. Each principal growth stage was classified in to secondary stages which described points in time or shorter developmental intervals in the major growth stage. This scale started with bud development (stage 0) and terminated at maturity of fruit (stage 8). The secondary stages were numbered 0 to 9 that described related percentile stages of growth. Several mesostages (1 to n) were used to describe the different vegetative and floral flushes during season for coding bud, leaf and shoot development. A list of phenological stages of mango, made in ascending order by sorting codes into numerical order, is presented in Table 1. A photo guide (Fig. 1) with codes was developed and used for uniform data recording at different locations.

Among seven principal growth stages, three principal growth stages were assigned to vegetative growth, which described the bud development (stage 0), leaf development on shoots (stage 1) and shoot elongation (stage 3), the later being shared with inflorescence emergence and flower development (stage 5). Flowering (stage 6), fruit growth (stage 7), fruit maturity (stage 8) completed the scale. First digit of the code depicts the principal growth stage ranging from 0 to 9.

The second digit of the scale was used for recognizing the mesostages occurred between the principal and secondary growth stages, ranged from 0 to n. The code was given on the basis of number of vegetative flushes and flowering occurred during the year. Generally, two mesostages (1, 2) were used for coding. However, it can be more than two according to the number of flushes found in the region or multiple bearing varieties. The use of codes for mesostages made the differentiation possible between the principal and secondary vegetative and flowering growth stages. The third digit of the codes were the numerical values from 0 to 9, which was related to per cent growth of buds, leaves, shoots, flower buds, panicle and fruit development.

Results and discussion

A large set of phenological data collected on Totapuri trees was difficult to handle manually for assessing the suitability of BBCH scale and thus it was subjected to a computer program specially developed for extracting information from the collected data matrix. The phenological behaviour of each selected shoot recorded on Totapuri was summarized on the basis of per cent shoot under particular stage at a specific time based on total number of selected shoots. BBCH scale based data was depicted in the form of line graph for identifying phenological stages with highest score during different standard weeks/months (Fig. 2a, 2b). The graph indicates changes occurring among different phenophases for the identified shoots during particular period and can identify the occurrence of the most frequent stage. The occurrence of the phenophases can be interpreted with reference to prevailing temperature and rainfall (Fig. 2c). Analysed data presented in the Fig. 2 depicts significant transition pattern of phenophases in mango.

Phenological data collated from first week of August 2010 (33) to last week of June 2011 (24) at Lucknow was used for analysis and graphical depiction. During August (33-36 standard week) highest percentage of shoots was of stage 010 and percentage was static from standard week 46 to 51 (November to December) indicating growth cessation period. From standard week 4 (Jan. last week), the frequency of 010 declined and started increasing from week 13, with a conspicuous peak during May indicating cyclic nature of mango growth. The decline in the percentage of shoots with stage 010 indicated the transformation of the stage to other phenophases. The high degree of variation in percentage of shoots at principal growth stages *viz.*, vegetative bud, leaf and shoot development were observed due to simultaneous transition of these stages during standard week 33 to 42 (Aug. to last week of Oct) and 4 to 24 (Jan. end to June end). The longer and shorter duration between 010 and 319 during different parts of the year indicated that slow and rapid growth period can be detected by using the scale.

The stages indicating inflorescence growth were observed from standard week 3 (Jan.) and continued till standard week 12 (March end). Stage 511 (initiation of inflorescence) and 517 (light green to crimson petal tips visible in some flowers) were recorded from standard week 3 to 11 and 10 to 12, respectively. This indicate the less time required for panicle growth by late emerging panicles. Stage 619 (fruit set) was observed between

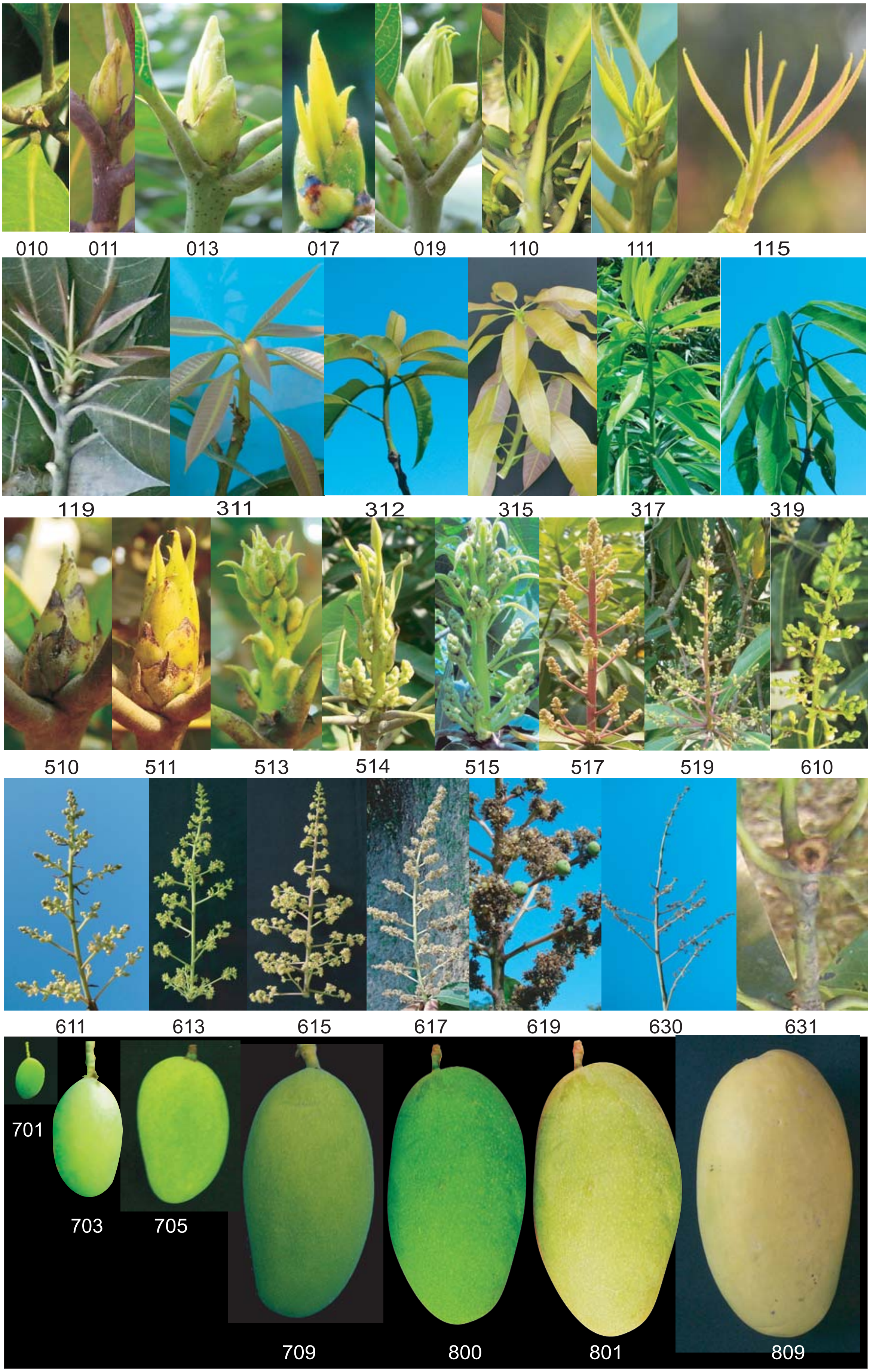

Fig. 1. Depiction of important phenophases for mango with corresponding codes. All phenophase photographs are not of cv. Totapuri and were found useful in identifying phenophases of *Mangifera indica* varieties.

Table 1. Extended BBCH scale used for mango (Hernández Delgado *et al.*, 2010)

Principal Growth Stage	Code	Description
0 Bud development		
First vegetative flush	010	Dormancy: leaf buds are closed and covered with green or brownish scales (Aubert and Lossois: vegetative stage A)
	011	Beginning of leaf bud swelling: bud scales begin to separate
	013	End of leaf bud swelling: scales completely separated, light green buds emerged (Aubert and Lossois: vegetative stage B)
	017	Beginning of bud break: light green to dark coppery tan leaf tips just visible (Aubert and Lossois: vegetative stage C)
	019	Bud break: light green to dark coppery tan leaf tips visible 5 to 10 mm above bud scales (Aubert and Lossois: vegetative stage D)
Second vegetative flush	020	Dormancy: leaf buds are closed and covered with green or brownish scales (Aubert and Lossois: vegetative stage A)
	021	Beginning of leaf bud swelling: bud scales begin to separate
	023	End of leaf bud swelling: scales completely separated, light green buds emerged (Aubert and Lossois: vegetative stage B)
	027	Beginning of bud break: light green to dark coppery tan leaf tips just visible (Aubert and Lossois: vegetative stage C)
	029	Bud break: light green to dark coppery tan leaf tips visible 5 to 10 mm above bud scales (Aubert and Lossois: vegetative stage D)
1 Leaf development		
First vegetative flush	110	Leaf tips more than 10 mm above bud scales
	111	First leaf unfolded
	115	More leaves unfolded: petioles visible
	119	All leaves completely unfolded and expanded
Second vegetative flush	120	Leaf tips more than 10 mm above bud scales
	121	First leaf unfolded
	125	More leaves unfolded: petioles visible
	129	All leaves completely unfolded and expanded
3 Shoot development		
First vegetative flush	311	Beginning of shoot growth: axes of developing shoots visible, about 10% of final length
	312	Shoots about 20% of final length
	315	Shoots about 50% of final length (Aubert and Lossois: vegetative stage A)
	317	Shoots about 70% of final length
	319	Shoots about 90% of final length
Second vegetative flush	321	Second vegetative flush beginning of shoot growth: axes of developing shoots visible, about 10% of final length
	322	Shoots about 20% of final length
	325	Shoots about 50% of final length (Aubert and Lossois: vegetative stage E)
	327	Shoots about 70% of final length
	329	Shoots about 90% of final length
5 Inflorescence emergence		
Principal flowering	510	Buds closed and covered with green or brownish scales
	511	Beginning of bud swelling: scales begin to separate (Aubert and Lossois: flowering stage A)
	513	Bud burst: first floral primordial just visible, panicle development begins (Aubert and Lossois: flowering stage B)
	514	Panicle axis begins to elongate, leaves are visible in mixed panicles
	515	Flowers are visibly separated, secondary axes begin to elongate (Aubert and Lossois: flowering stage D)
	517	Secondary axes elongated, flower buds are swollen and first light green to crimson petal tips visible in some flowers. In mixed panicles, leaves have reached final length
	519	End of panicle development: fully developed secondary axes, many flowers with green to crimson petal tips visible and some opened, leaves fully developed in case of mixed panicles
Secondary flowering	520	Axillary flower buds of the apical dome are closed and covered with green or brownish scales
	521	Beginning of bud swelling: scales begin to separate (Aubert and Lossois: flowering stage A)
	523	Bud burst: first floral primordia just visible, panicle development begins (Aubert and Lossois: flowering stage B)
	525	Flowers are visibly separated, secondary axes begin to elongate (Aubert and Lossois: flowering stage D)
	527	Secondary axes elongated, flower buds are swollen and first light green to crimson petal tips visible in some flowers. In mixed panicles, leaves have reached to its final length
	529	End of panicle development: fully developed secondary axes, many flowers with green to crimson petal tips visible and some opened. Leaves fully developed in case of mixed panicles
6 Flowering		
Principal flowering	610	First flower open
	611	Beginning of flowering: 10% of panicle flowers open
	613	Early flowering: 30% of panicle flowers open
	615	Full flowering: more than 50% of panicle flowers open (Aubert and Lossois: flowering stage E)
	617	Flower fading: majority of petals fallen or dry
	619	End of flowering: all petals fallen or dry, fruit set
	630	Barren panicle
	631	Panicle completely dried or dropped
Secondary flowering	620	First flowers open
	621	Beginning of flowering: 10% of panicle flowers open
	623	Early flowering: 30% of panicle flowers open
	625	Full flowering: more than 50% of panicle flowers open (Aubert and Lossois: flowering stage E)
	627	Flower fading: majority of petals fallen or dry
	629	End of flowering: all petals fallen or dry, fruit set
	630	Barren panicle
	631	Panicle completely dried or dropped
7 Fruit development		
Main season fruit development	701	Fruits at 10% of final size, styles still visible. Beginning of physiological fruit drop (Aubert and Lossois: fruit set stage A)
	703	Fruits at 30% of final size, end of physiological fruit drop. (Aubert and Lossois: fruit set stage B)
	705	Fruits at 50% of final size
	709	Fruits at standard cultivar size, shoulders fully developed
8 Maturity of fruit		
Main season fruit maturity	800	Physiological maturity: fruit fully developed, pulp creamy green in colour.
	801	Beginning of skin colour change (colour break stage)
	809	Fruit colour fully developed. Fruit ripe for consumption, with correct firmness and typical taste

standard week 12 and 16. The stages for fruit development (701 to 709) were recorded during standard weeks 16 to 24. The stage 911 in standard weeks 12 to 16 indicated the existence of barren panicles due to drying or dropping of flowers from the panicles, while in later standard weeks, such as, from week 17 and onwards, stage 911 represented the barren panicle after fruit drop. These are few examples of interpretation of BBCH scale data. A perusal of analysed data also revealed that the existing BBCH scale is suitable for studying the mango phenology with few exceptional aspects. Thus, modifications in the existing scale (Hernández *et al*., 2011) are presented (Table 2) to meet out the missing aspects of the basic principles of BBCH scale (Hack *et al.*, 1992).

As a matter of fact, researchers developed their own scale (Aubert and Lossois, 1972), used older non-uniform scales or adopted BBCH scale (Hernandez *et al.*, 2011) to study mango phenology. Nevertheless, this has led to the interpretation of scales in different ways, leading to inconsistency in comparing research results. The proposed scale attempts to unify the description for mango and make it possible to address difficulties in interpretation of other researches related with specific phenophase sampling. General interpretation of collected data using the scale can also form the basis for the development of future scales specific to tropical and subtrpical fruit tree crops including mango.

Limitations of existing BBCH scale: Based on the data collected from diverse mango growing locations and literature on the application of BBCH scale for mango (Hernandez Delgado *et al.*, 2011), following questions were encountered which require attention of researchers for improvement in scale or development of methodology for providing precise description of the major phenophases in mango. At initial panicle or shoot development stage, the per cent growth of vegetative shoots (311 to 315), flowering (611 to 615) or fruit development stage (701 to 705) can not be assigned/predicted precisely, thus the assumptions made at the time of data recording on the basis of existing BBCH scale for mango may make it erroneous. The actual observation depends on the degree of precision employed by the user. Sometimes, more than one vegetative bud emerge as a result of further growth in previous year bearing shoots, identified as stage 916. Some of the stages (drying of shoots) seen in the field conditions necessitate the selection and tagging of new shoot for data collection and data collected on dried shoot may become irrelevant. Some of the stages (010 and 510) appear morphologically same but their further developments are totally different. The codes 630 and 631 indicating the barren and completely dried/dropped panicle, respectively, is not well defined and accurate according to the general BBCH scale.

Modifications in existing scale: Although the existing extended BBCH–scale for mango can be used widely without any modification because it describes developmental stages of bud, shoot, leaf and fruit development, even inflorescence and panicle development. Yet some of the modifications are suggested to make it more useful for phenological studies. Additional characteristics of the proposed scale for mango are given in Table 2.

In the context of phenology related studies, mango has specific vulnerability, such as perennial nature, complex flowering, warming impacts on floral bud phenology (Schnell and Knight, 1998). Numerous data on phenology, collected (in past) in contrasting climatic conditions (location, period) highlighting significant deviations in dates of different phenological stages may not be comparable without adopting uniform phenological data recording scale/methodology. The current modified BBCH scale is easy to use for studying different growth stages of mango and includes all the subtle details of the mango growth and development in one scale. It is uniform, simple to use and can be used for computer aided analysis. Furthermore, modified BBCH-scale also distinctly separates various vegetative flushes as well as the terminal and axillary flowering which are important for planning mango orchard management practices.

Table 2. Additions to the existing BBCH scale for mango

Stage	Code	Description
7 Fruit development stage		
Main season fruit development	711	Styles still visible, beginning of physiological fruit drop
	713	End of physiological fruit drop
	715	Fruit at 50 % of final size
	719	Fruit at standard cultivar size, shoulders fully developed
Second season fruit development	721	Styles still visible, beginning of physiological fruit drop
	723	End of physiological fruit drop
	725	Fruit at 50 % of final size
	729	Fruit at standard cultivar size, shoulders fully developed
8 Maturity of fruit		
Main season fruit development	810	Physiological maturity: fruit fully developed, flesh creamy green in colour
	811	Beginning of skin colour change
	819	Fruit colour fully developed. Fruit ripe for consumption, with correct firmness and typical taste
Second season fruit development	820	Physiological maturity: fruit fully developed, flesh creamy green in colour
	821	Beginning of skin colour change
	829	Fruit colour fully developed. Fruit ripe for consumption, with correct firmness and typical taste
9 Senescence		
Principal vegetative flush/ flowering	911	Barren panicle. Fruit dropped
	916	Dried shoots or dried/dropped-off panicle
Second vegetative flush/ flowering	921	Barren panicle. Fruit dropped
	926	Dried shoots or dried/dropped-off panicle

Keeping existing BBCH scale in view, the proposed modified BBCH scale is further a step forward in achieving uniformity of growth stage descriptions and can be adopted widely for mango. Based on the requirements for detailed phenological studies on mango, refinement of the modified scale may further pave way for the development of more robust scale. Intensive data collection from diverse ecologies and its analysis will lead to further refinement. However, in absence of such advancements, the present endeavour will help in harmonious phenological data recording at various location and data analysis.

Acknowledgements

We thank Dr. H. Ravishankar, Director, CISH, Lucknow and Dr. C.P.A. Iyer, Chairman, Consortium Advisory Committee for encouragement during study. The authors gratefully acknowledge the financial support from NAIP, ICAR, New Delhi and thank Dr. S. Kochhar, National Coordinator and Dr. Bengali Baboo, National Director, NAIP for their encouragement; Dr. P.M. Hernández Delgado and Dr. V. Galán Saúco Instituto Canario

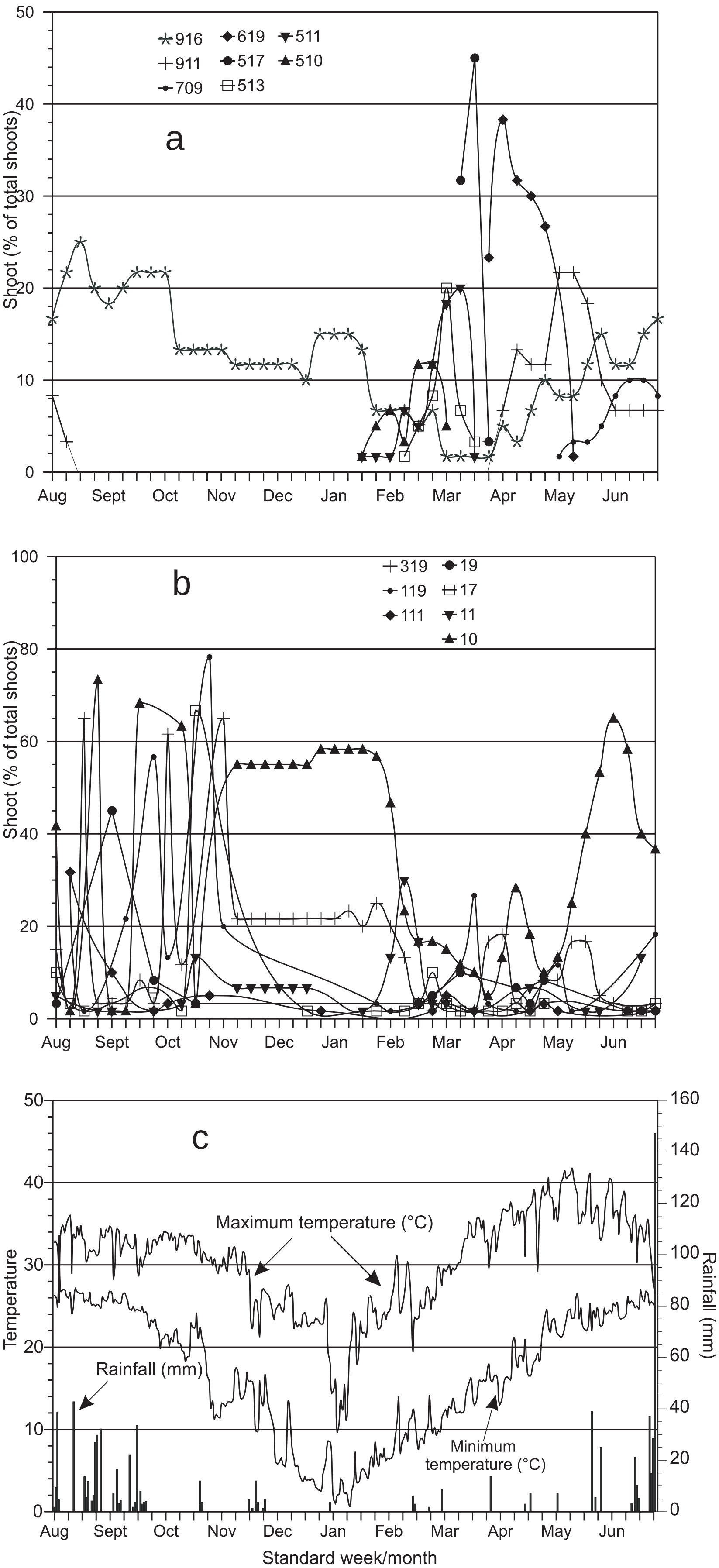

Fig. 2. BBCH scale based percentage of shoots during different standard weeks (a&b) temperture and rainfall pattern during the period(c). See code details in Table 1.

de Investigaciones Agrarias, Ctra, de El Boquerón, Valle Guerra, Tenerife, Spain for sharing published information on mango phenology.

References

Agustí, M., S. Zaragoza, H. Bleiholder, L. Buhr, H. Hack, R. Klose and R. Stauss, 1997. Adaptation de léchelle BBCH à la description des stades phénologiques des agrumes du genre Citrus, *Fruits*, 52: 287-295.

Anderson, Dean P., Erik. V. Nordheim, T.C. Moermond, Z.B. Gone Bi and Christophe Boesch, 2005. Factors Influencing tree phenology in Ta¨ı National Park, Cˆote d'Ivoire. *Biotropica*, 37(4): 631-640.

Aubert, B. and P. Lossois, 1972. Considerations sur la phenologie des especes fruitieres arbustives. *Fruits*, 27(4): 269-286.

Bleiholder, H., T. van den Boom, P. Langeluddeke and R. Stauss, 1989. Einheitliche Codierung der phanologischen Stadien bei Kultur- und Schadpflanzen, *Gesunde Pflanzen*, 41: 381-384.

Cautin, R. and M. Agusti, 2005. Phenological growth stages of the cherimoya tree (*Annona cherimola* Mill.). *Scientia Horticulturae*, 105(4): 491-497.

Feller, C., H. Bleiholder, L. Buhr, H. Hack, M. Hess, R. Klose, U. Meier, R. Stauss, T. van den Boom and E. Weber, 1995a. Phänologische Entwicklungsstadien von Gemüse. I. Zwiebel-, Wurzel-, Knollen- und Blattgemüse, *Nachrichtenblatt des Deutschen Pflanzenschutzdienstes*, 47: 193-206.

Feller, C., H. Bleiholder, L. Buhr, L. Hack, M. Hess, R. Klose, U. Meier, R. Stauss, T. van den Boom and E. Weber, 1995b. Phänologische Entwicklungsstadien von Gemüse. II. Fruchtgemüse und Hülsenfrüchte, *Nachrichtenblatt des Deutschen Pflanzenschutzdienstes*, 47: 217-232.

Fleckinger, J. 1948. Les stades végétatifs des arbres fruitiers en rapport avec les traitements. *Pomologie Française*, 81-93.

García-Carbonell, S., H. Yagüe, H. Bleiholder, H. Hack, U. Meier and M. Agustí, 2002. Phenological growth stages of the persimmon tree (*Diospyros kaki*), *Ann. Appl. Biol.*, 141: 73-76.

Hack, H., H. Bleiholder, L. Buhr., U. Meier, U. Schnock-Fricke, E. Weber and A. Witzenberger, 1992. Einheitliche Codierung der phanologischen Entwicklungsstadien mono- und dikotyler Pflanzen - Erweiterte BBCH-Skala, Allgemein. *Nachrichtenbl. Deut. Pflanzenschutzd*. 44: 265-270.

Hack, H., H. Gall, T. Klemke, R. Klose, U. Meier, R. Stauss and A. Witzenberger, 1993. The BBCH-scale for phenological growth stages of potato (*Solanum tuberosum* L.), *Proceedings of the 12th Annual Congress of the European Association for Potato Research* Paris, 153-154.

Hernández Delgado, P.M., M. Agusti, M. Aranguren, D. Fernandez Galvan, V. Galan Sauco and C. Reig, 2010. Phenological development stages of mango (*Mangifera indica* L.) according to the BBCH scale. *In: 9th International Mango Symposium* held during 8-12 April, Sanya, Hainan Island, China, 72.

Hernández Delgado, P.M., M. Aranguren, C. Reig, D. Fernandez Galvan, C. Mesejo, A. Martinez Fuentes, V. Galan Sauco and M. Agusti, 2011. Phenological growth stages of mango (*Mangifera indica* L.) according to the BBCH scale. *Scientia Horticulturae*, 130: 536-540.

Kushwaha, C.P. and K.P. Singh, 2008. India needs phenological stations network. *Current Science*, 95(7): 832-834.

Lancashire, P., H. Bleiholder, T. van den Boom, P. Langelüddeke, R. Stauss, E. Weber and A. Witzenberger, 1991. A uniform decimal code for growth stages of crops and weeds, *Ann. Appl. Biol.*, 119: 561-601.

Lorenz, D., D. Eichorn, H. Bleiholder, R. Klose, U. Meier and E. Weber, 1994. Phänologische Entwicklungsstadien der Weinrebe (*Vitis vinifera* L. ssp. vinifera). Codierung und Beschreibung nach der erweiterten BBCH-Skala, *Vitic. Enol. Sci.,* 49: 66-70.

Martinez-Calvo, J., M. Badenes, G. Llacer, H. Bleiholder, H. Hack and U. Meier, 1999. Phenological growth stages of loquat tree (*Eryobotria japonica* thumb. lindl.), *Ann. Appl. Biol.*, 134: 353-357.

Meier, U., H. Garf, H. Hack, M. Hess, W. Kennel, R. Klose, D. Mappes, D. Seipp, R. Stauss, D. Streif and T. van den Boom, 1994. Phänologische Entwicklungsstadien der Kernobstes (*Malus domestica* Borkh. and *Pyrus communis* L.), des Steinobstes (*Prunus*-Arten), der Johannisbeere (*Ribes*-Arten) und der Erdbeere (*Fragaria* x *ananassa* Duch.). Codierung und Beschreibung nach der Erweiterten BBCH-Skala, mit Abbildungen, Nachrichtenbl. *Deut. Pflanzenschutzd*., 46: 141-153.

Meier, U., L. Bachmann, E. Buhtz, H. Hack, R. Klose, B. Märländer and E. Weber, 1993. Phänologische Entwicklungsstadien der Beta-Rüben (*Beta vulgaris* L.). Codierung und Beschreibung nach der erweiterten BBCH-Skala mit Abbildungen, *Nachrichtenbl. Deut. Pflanzenschutzd*., 45: 37-41.

Melgarejo, P., R. Martinez-Valero, J. Guillamón, M. Miró and A. Amorós, 1997. Phenological stages of the pomegranate tree (*Punica granatum* L.), *Ann. Appl. Biol.*, 130: 135-140.

Parrado-Rosselli, Angela, Jose-Luis Machado and Tatiana Prieto-L´opez, 2006. Comparison between two methods for measuring fruit production in a tropical forest. *Biotropica*, 38(2): 267-271.

Sanz-Cortés, F., J. Martínez-Calvo, M.L. Badenes, H. Bleiholder, H. Hack, G. Llácer and U. Meier, 2002. Phenological growth stages of olive trees (*Olea europea*), *Ann. Appl. Biol.*, 140: 151-157.

Schnell, R.J. and R.J. Knight, 1998. Phenology of flowering among different mango cultivars. *Proc. Fla. State Hort. Soc*., 111: 320-321.

Zadoks, J., T.T. Chang and C.F. Konzack, 1974. A decimal code for the growth stages of cereals. *Weed Res.*, 14: 415-421.

Received: October, 2011; Revised: November, 2011; Accepted: December, 2011